# The Vegetation of the Lake Michigan Shoreline in Wisconsin

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Maps of the bedrock geology and glacial geology of Wisconsin were obtained from the Geological and Natural History Survey, University of Wisconsin Extension.

## ABSTRACT

Vegetation of the Lake Michigan shoreline, from the Illinois border to eastern Door County, was examined and sampled at thirty-one sites. Supplementary information was obtained from aerial photographs, topographic maps and reports from the land surveys of ca. 1830-1840. The remnant native and disturbed plant communities were found to be associated with the following shoreline types: (1) bays and estuaries; (2) beaches; (3) sand dunes and ridges; (4) gently sloping bluffs and lake terraces; (5) steep, eroding clay banks; (6) ravines and eroding bluffs; (7) dolomitic rock outcroppings; (8) disturbed and landfill areas. These plant assemblages were investigated to determine their areal extent, species-composition (including rare, endangered and threatened species) and relationship to the physical characteristics of these shoreline habitats.


## INTRODUCTION

The increased erosion and mass wastage of the shorelines of all the Great Lakes during the early 1970s stimulated considerable interest in the causes and probable solutions to these processes. Vegetation cover was early recognized as important in slowing some erosional processes; however, studies on the interrelationships of plant species and plant communities and shoreline stabilization on the Great Lakes are few and limited and in shoreline management the potential values of vegetation have been sadly neglected. This report describes the types of vegetation which occur in various shoreline habitats, maps their geographic location and discusses some of their ecological characteristics. Since the role of vegetation in reducing erosion has never been properly assessed in the lower Great Lakes, especially Lake Michigan, this report details some of the relationships between vegetation and environmental factors which may be of significance in plans for coastal zone management.

## The Role of Vegetation in Erosion Control

Shoreline erosion is the result of both marine and terrestrial processes. Marine processes produce erosion through wave action, lake currents, wind and offshore ice movement, while terrestrial processes include surface water runoff, ground water seepage, and frost action. These processes and their results have been described in reports of Quigley and Tutt (1968), U.S. Army Corps of Engineers (1971), Gelinas and Quigley (1973), Omohundro (1973), Hadley (1976), Rosenbaum (1976) and Edil and Vallejo (1976). However, these studies listed emphasize physical factors and include little or no reference to shoreline vegetation.

The function that vegetation may play in slope and shoreline stabilization has been briefly described by Gray (1974, 1975, 1976), Hall and Ludwig (1975) and Environment Canada (1976). These reports indicate that the most significant contribution in erosion control is the influence of vegetation on slope processes and for stabilization of aeolian material. Vegetation may reduce erosional processes in several ways as follows:

(1) by soil retention through binding of the soil particles by roots.

(2) through interception of precipitation and reducing runoff during storms.

(3) by depletion of soil moisture through transpiration thus aiding in the reduction of hydrostatic pressures on slopes.

(4) by stabilizing dunes and drifting sands.

(5) by maintaining good conditions for infiltration of water, thus reducing runoff.

Vegetation offers only limited protection against direct wave action and other marine processes and cannot effectively hold steep cliffs or bluffs influenced by wave action. In such situations, vegetation may serve to aid mechanical and engineering controls.

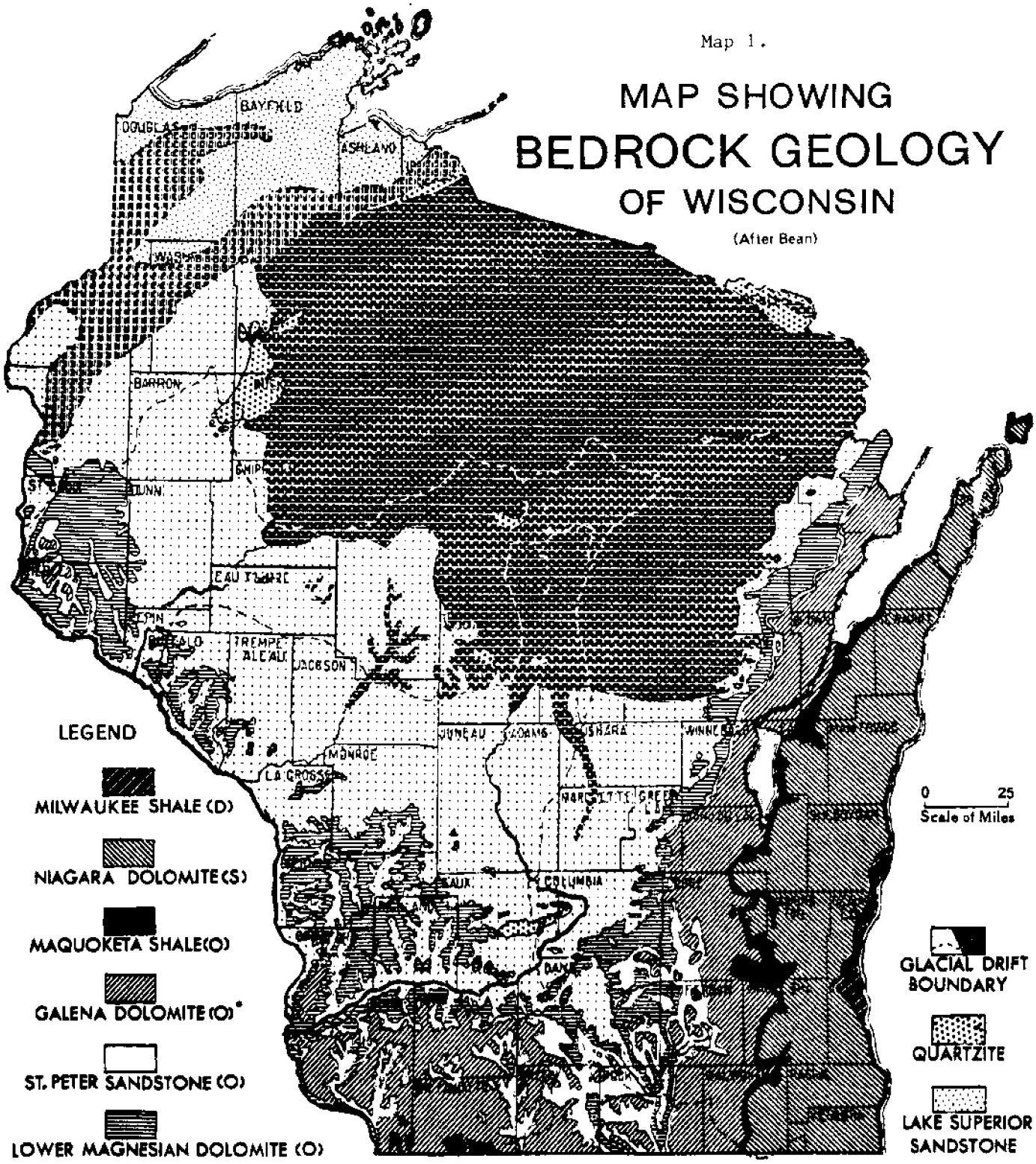
## Geological History and Features of the Western Lake Michigan Shoreline.

In eastern Wisconsin the predominant bedrock is the Niagara Dolomite (Silurian) with some areas of Milwaukee Shale (Devonian). Outcrops of the shale lie chiefly offshore and the dolomite appears at the surface only in a few quarries (Map 1) in northeastern Milwaukee, Ozaukee and Sheboygan Counties. The dominant topographic features of the west shoreline of Lake Michigan are the result of glaciation in the pre-Lake Michigan basin during the Cary, Woodfordian and Valders Substages of Wisconsin ice. Black (1970) dates the Cary and Woodfordian substages as between 13,000 and 20,000 years B.P. and the Valders between 11,000 to 12,500 years B.P. During these substages a series of moraines were deposited parallel to the present lake shore (Map 2). These deposits provide the parent material of the clay banks which are prominent in sections of the present-day shoreline.

Map 1.

# MAP SHOWING BEDROCK GEOLOGY OF WISCONSIN

(After Bean)

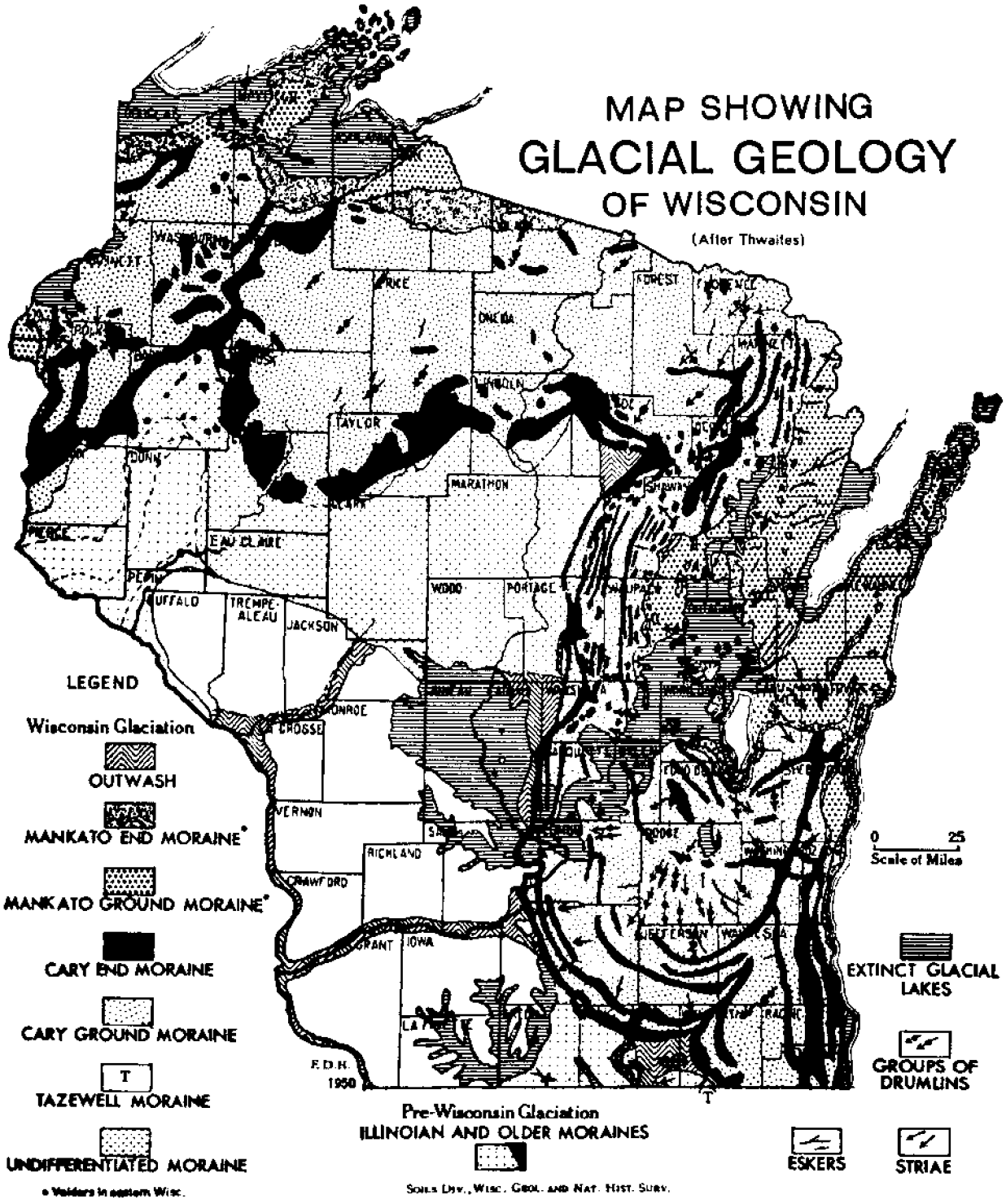



Soils Div., Wisc. Geol. and Nat. Hist. Surv.

* and Platteville.

*Note*: In legend, left, formations are in order of age, youngest at top.

F. D. H., 1950



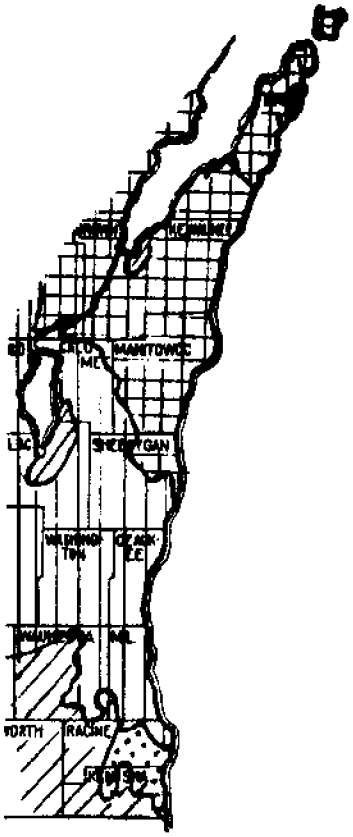

Map 2. Glacial Geology of Wisconsin.

As the ice sheets retreated northward, meltwater accumulated in the basin between the icefront and the higher land surrounding the basin. This formed glacial lakes which were predecessors of the present Lake Michigan. The surface of one of these ancient lakes, Lake Chicago, was about 55 feet above the modern lake level (Goldthwait, 1917) and discharged southward into the Illinois River. As the ice sheets continued to retreat and the lake expanded northward, its level was gradually lowered and the adjacent shoreline was subjected to erosional processes (Alden 1918; Goldthwait 1907; Thwaites and Bertrand 1957; Hough 1958). The retreat continued and Lake Chicago merged with other ancestral Great Lakes (Lake Algonquin and Lake Nipissing) and developed a drainage eastward into the St. Lawrence River. Accompanying development of this drainage, uplift to the northeast caused a tilting of the Great Lakes basin which resulted in a continued lowering of the level of Lake Michigan until the present level was established. In recent time there have been minor water level fluctuations, but features of the earlier shoreline development remain above the present lake level. Such shoreline features include steep clay banks, lake terraces, sandy beaches, ridges and dunes, eroded rock outcroppings and estuarine bays and coves. All of these have been altered to some extent by continuing terrestrial and marine erosion. Also, major ravines have been formed by streams cutting through the glacial deposits and discharging into the lake. Further shoreline modifications have occurred in post-settlement time by shoreline development for commercial, industrial, agricultural, residential and recreational purposes.

These physiographic features were rapidly covered by plants characteristic of the climate, soils and drainage conditions of post-glacial time. It is known that prior to white settlement in the area, the shoreline vegetation consisted of northern mesic and boreal forest communities north of Sheboygan County, southern mesic forest from Sheboygan County to northeastern Racine County and oak savannas and prairies in southeastern Racine and Kenosha Counties (Map 3). This pattern has been reconstructed from the records of the original land surveys of ca. 1835-1840 (Goder 1957; Klahorst 1949; and others) and has been described in various publications (Curtis 1959; Stearns and Kobriger 1975). Remnants of these broad vegetation types follow a similar geographic distribution today and may be subdivided into plant communities found typically on specific shoreline habitats. These habitats are conditioned by the nature of the parent material, stability of slopes and erosion processes, climatic fluctuations and human modifications. The plant communities described in this report may be associated with the following shoreline types: (1) bays and estuaries; (2) beaches; (3) sand dunes and ridges; (4) sloping bluffs and lake terraces; (5) steep, eroding clay banks; (6) ravines and eroding bluffs; (7) dolomitic rock outcroppings; (8) disturbed and/or filled areas. See Fig. 1.

Method of Study.

Aerial photographs and U.S. Geological Survey topographic maps were examined to determine locations of the various shoreline features from the Illinois border to the tip of Door County. Representatives of each type were visited in September and October 1975 and locations were chosen for detailed



Boreal Forest

Northern Mesic Forest

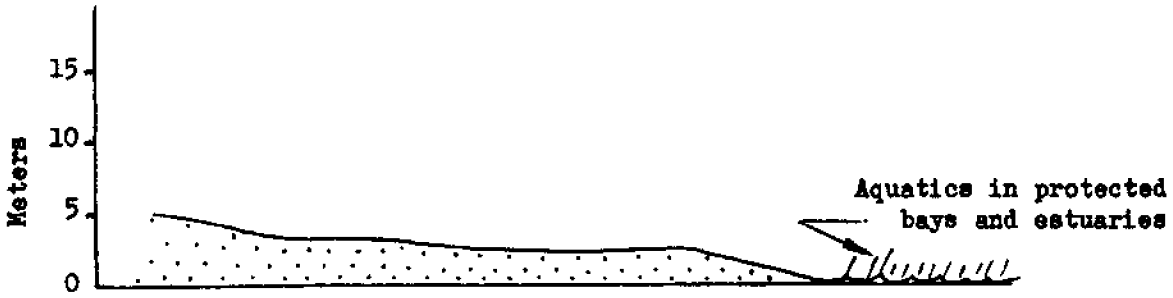
Southern Mesic Forest

Oak Savanna

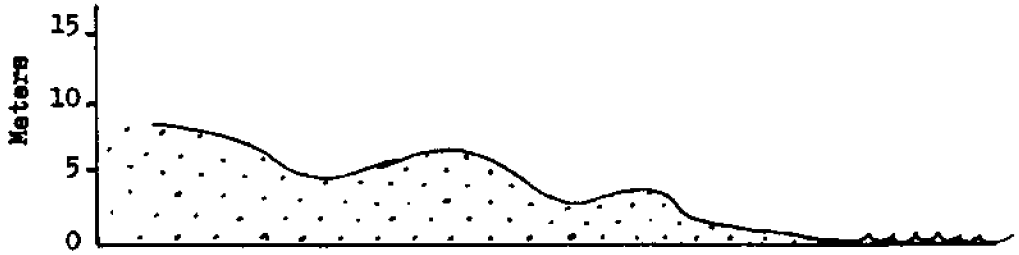
Prairie

Map 3. Early Vegetation of Wisconsin, ca. 1840 (Adapted from Curtis, 1959).

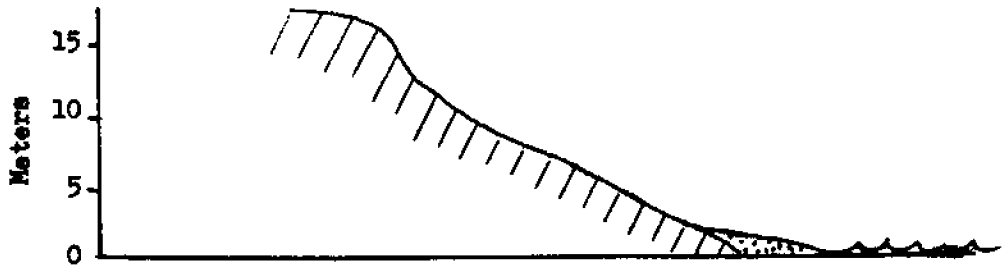
Figure 1. Types of Lake Shore Profiles in Eastern Wisconsin.



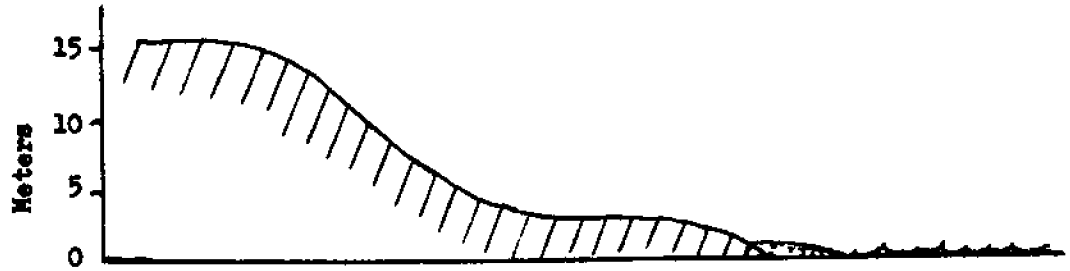

(A) Gentle slope with sandy beach.



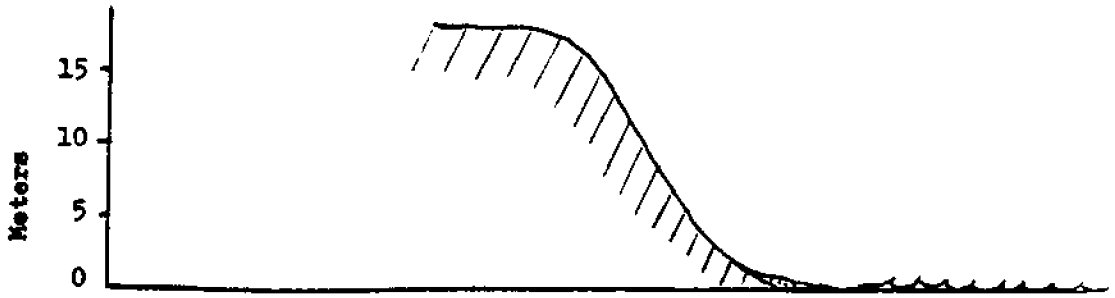

(B) Dunes, ridges, swales and sandy beach.



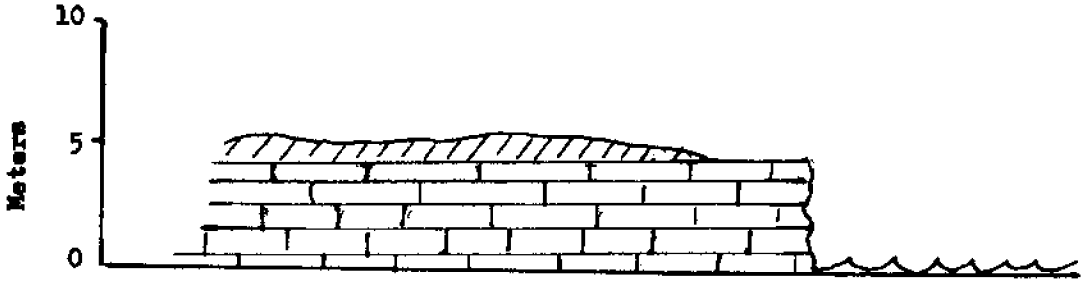

(C) Medium slope, $< 35^{\circ}$, with sandy beach.



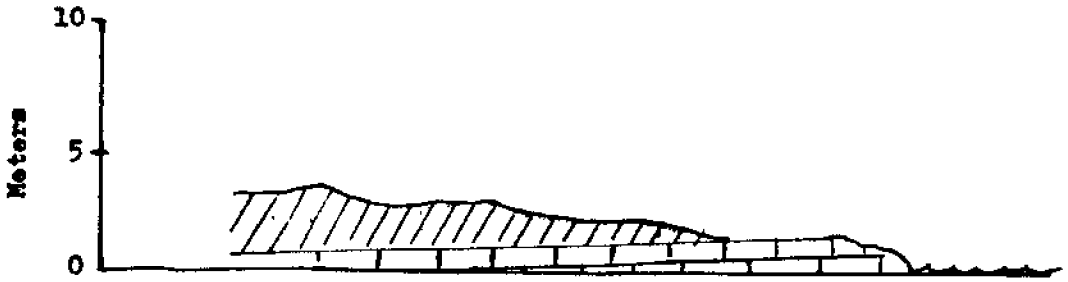

(D) Medium to steep slope with lake terrace and sandy or gravelly beach.



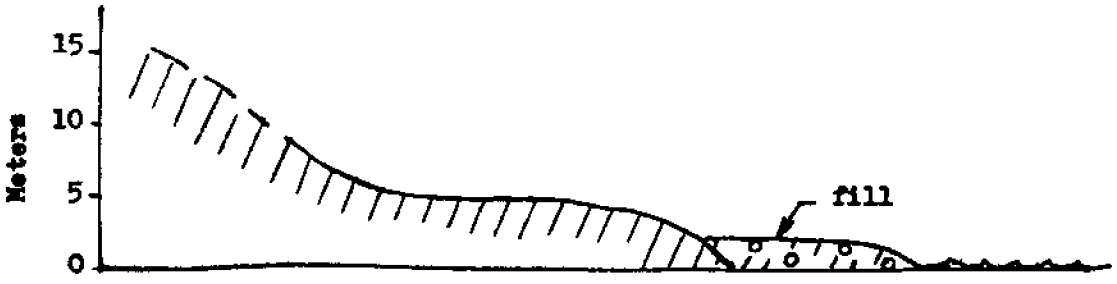

(E) Steep slope, >35°, with narrow sandy or gravelly beach.




(F) Rocky bluff.




(G) Rock outcrop.

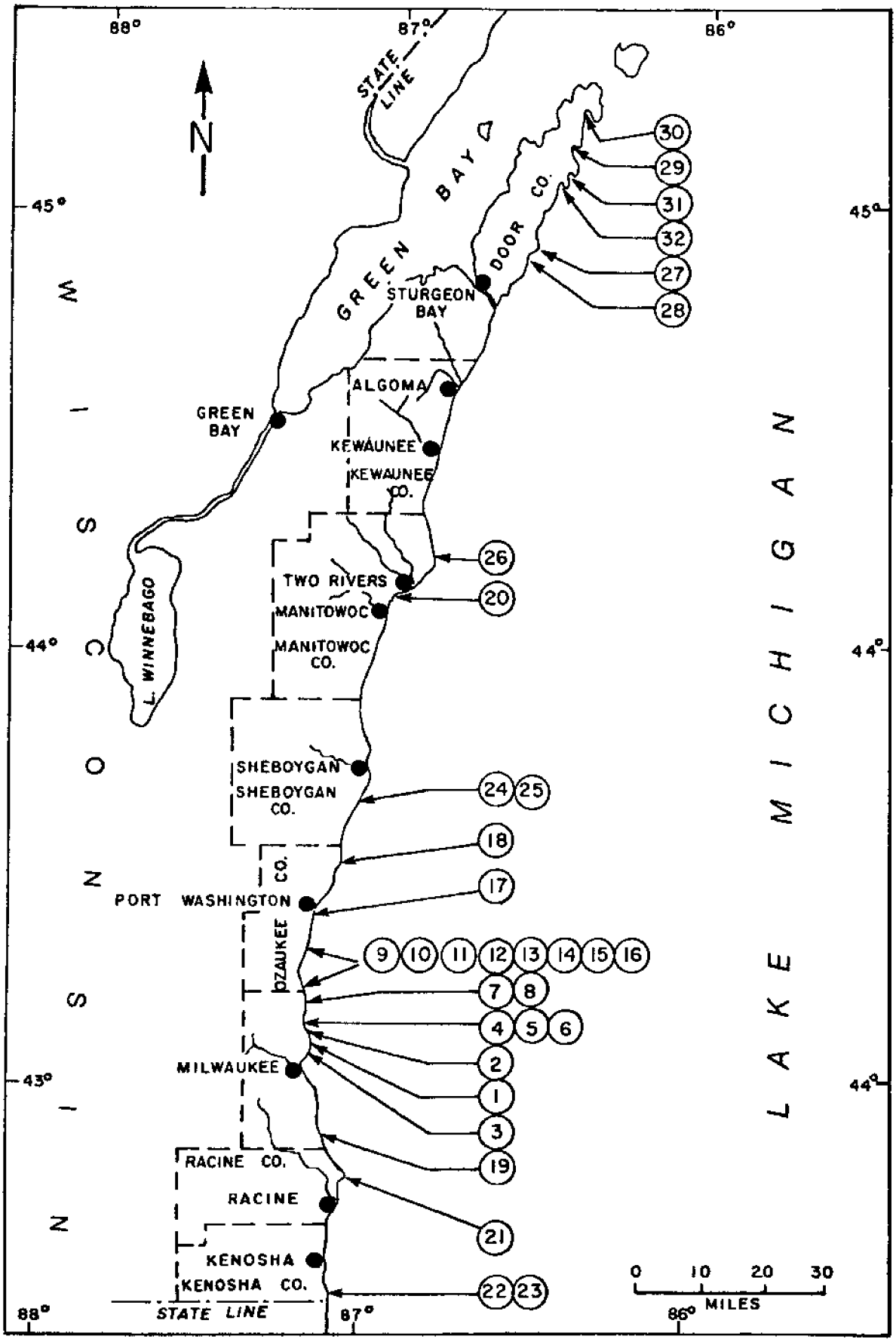



(H) Modified shoreline.

study. Field work was carried out from late May through August 1976 at 32 sites (Map 4). At each site, one or more transects, 100 m in length and 1 m and 2 m wide, were established, oriented at right angles to the shoreline and extending inland from the high water mark. Each transect was divided into 10 meter segments. Presence, cover, abundance and sociability were recorded for trees, shrubs and understory plants for each segment. Trees were recorded in the 2 x 10 m segments and shrubs and herbs in 1 x 10 m units. Voucher specimens were collected of many species and are filed in the Herbarium of the University of Wisconsin-Milwaukee. The nature of the parent material (or soil), degree and stability of the slope, relative extent of beach and current land use were noted. A general survey was made of each area outside of the study plot to record individuals or colonies of rare, threatened or endangered plant species and to note features of historical, scientific or esthetic significance. Nine additional sites were visited but were not sampled because they proved not sufficiently distinct from those already studied.

This report summarizes the distribution of established plant communities geographical location and extent, species composition and relationship to the physical characteristics of the shoreline habitats in which they occur. The condition of each shoreline type is considered in terms of present-day usage. Threatened, rare and endangered species (Read 1976) as well as characteristic plants are discussed for each community (Appendix III).

Species lists are included in Appendix II. Common names, with scientific names in parentheses, are used throughout the report. Nomenclature generally follows Gleason and Cronquist (1963) but newer taxonomic designations are used when known.




Map 4. Locations of study sites. Specific locations are described in Appendix I.

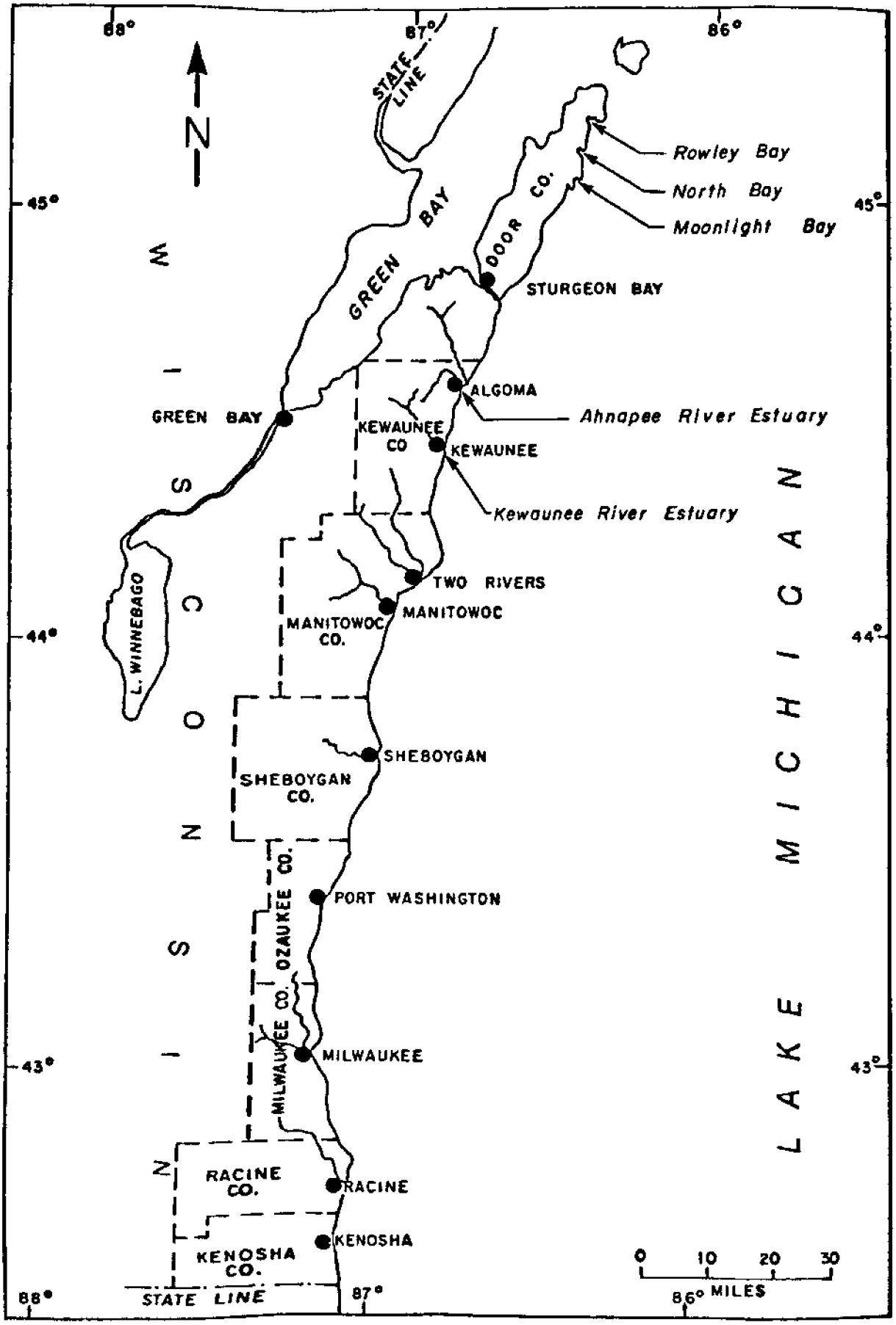
## SHORELINE TYPES

### Bays and Estuaries

The shallow waters along the western Lake Michigan shoreline are generally devoid of vascular aquatic plants. The severe wave action and the unstable bottom sands prevent plant establishment. North of Green Bay, for example, many communities of emergent aquatic plants have been destroyed during the high water of recent years. However, a few habitats possess sufficient stability for plants to become established. These include estuarine bays at the mouths of the Kewaunee and Ahnapee (Algoma) Rivers in Kewaunee County and several protected bays and coves in Door County (Map 5). Today only a few emergent aquatic communities persist inland from the mouths of these rivers. In contrast, in presettlement time the mouths of these and other rivers discharging into the lake contained considerable areas of marshland with such typical aquatics as bulrushes (Scirpus, spp.; Juncus spp.) burreed (Sparganium spp.) and cattail (Typha latifolia). The development of harbors and industrial structures and the accompanying land-filling and channeling of rivers destroyed most of these original aquatic communities.

Several protected bays and coves in Door County are sufficiently remote from any significant commercial development to retain well- developed aquatic communities. Detailed investigation of these communities was not possible but a list of species was compiled from shore observations and estimates were made of their numbers and general distribution. These observations were made along the west shores of North Bay (Site No. 29) and Rowley Bay (Site No. 30) and along the south shore of Moonlight Bay, at Toft Point (Site No. 31). The great bulrush (Scirpus validus) was the most common emergent aquatic species and colonies of this plant extended from the shore a distance of 50 meters into both North Bay and Rowley Bay. Water smartweed (Polygonum natans), an undetermined milfoil (Myriophyllum sp.) and an unidentified pond weed (Potamogeton sp.) also were observed in the deeper water. The common cattail (Typha latifolia), reed canary grass (Phalaris arundinacea), arrowhead (Sagittaria latifolia), bur-reed (Sparganium eurycarpum), giant reed (Phragmites communis) and blue-joint (Calamagrostis canadensis) grow in the shallow water adjacent to the shoreline. On the low moist banks of Rowley Bay and North Bay an assemblage of plants were noted which may be classified as a shrub-carr community. Shrubs predominate with the red osier dogwood (Cornus stolonifera) as the most important member. Others of the shrub component include ninebark (Physocarpus opulifolius), speckled alder (Alnus rugosa), meadow sweet (Spiraea alba) and saplings of white cedar (Thuja occidentalis) and quaking aspen (Populus tremuloides). Common herbs in this community include sedges (Carex spp.), turtlehead (Chelone glabra), white snakeroot (Eupatorium rugosum), late goldenrod (Solidago gigantea), joe-pye weed (Eupatorium maculatum), marsh bellflower (Campanula aparinoides), closed gentian (Gentiana andrewsii) and jewel-weed (Impatiens biflora).

At the mouths of the Mink River, a sluggish stream which discharges into Rowley Bay, and of an unnamed stream which discharges into North Bay, floating and emergent aquatic plants occur including such species as the spadderdock or yellow water lily (Nuphar variegatum), water smartweed (Polygonum natans), arrowhead (Sagittaria latifolium), burreed (Sparganium eurycarpon), and wild rice (Zizania aquatica).




Map 5. Locations of bays, coves and estuaries with established vascular aquatic plants.

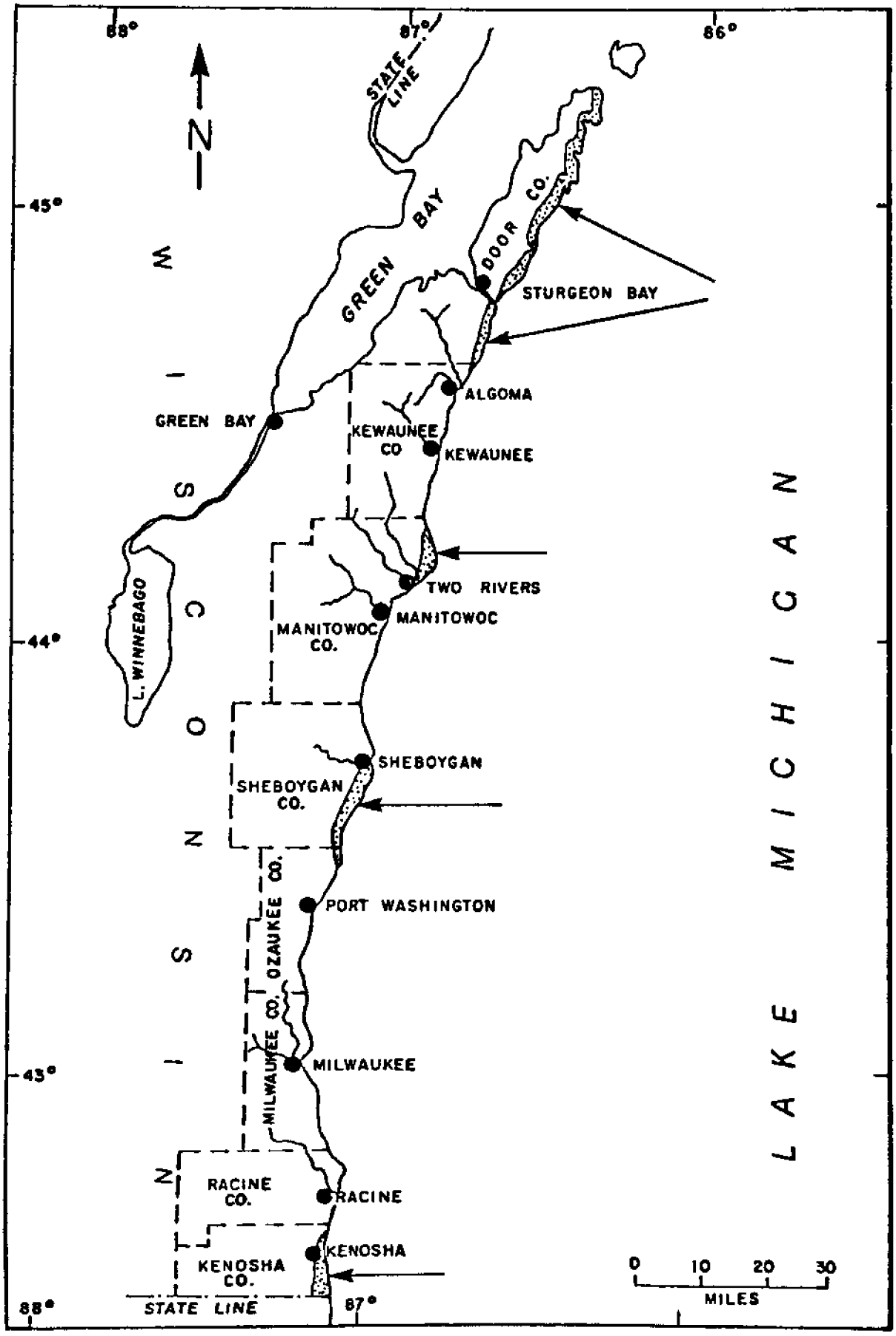
Because the species composition of the emergent aquatic and shrub-carr communities of the Lake Michigan bays and coves are different from similar communities associated with inland lakes (Curtis 1959), they are worthy of more detailed investigation than they have received to date. These aquatic communities are especially important as they provide excellent habitats for fish, waterfowl and other aquatic and terrestrial wildlife. Furthermore, emergent stands of vegetation tend to slow wave velocity, and speed up the settling and entrapment of sediments thereby reducing turbidity and, to a limited extent, aid in slowing shoreline erosion. Most of the shoreline along these bays, coves and estuaries is in private ownership and is used chiefly for seasonal recreation. It is highly desirable to maintain this shoreline in its present state. To do this may require restrictions on industrial development along the shoreline and diversion of residential effluent away from these waters.

## Beaches, Ridges and Sand Dunes

Although sandy beaches of varying widths are found scattered along the entire western Lake Michigan shoreline, they are most extensive where lacustrine sands were deposited in extinct glacial lakes. In these localities, a series of ridges and swales are usually present paralleling the old shoreline. Some of the ridges have been altered by wind erosion to form dunes. This shoreline type is best developed in the following areas: (1) Kenosha County: from the Illinois border to the southern limits of the city of Kenosha; (2) Ozaukee and Sheboygan Counties: north of the Town of Belgium, east of the Town of Oostburg and northward to the southern limits of the city of Sheboygan; (3) Manitowoc County: 2-3 miles north of the city of Manitowoc, northward to approximately 10 miles north of the city of Two Rivers; (4) Door County: from Whitefish Bay, northward to the tip of the peninsula, except in areas of dolomitic outcrops at Cave Point, Toft Point and Newport (Map 6).

Sandy shorelines have distinct slope profiles (Fig 1(A)), the result of both water and wind erosional and depositional processes. The area from the water's edge to the extent of the highest storm waves is the beach or strand zone. Fluctuations in water level and unpredictable storm waves cause this habitat to be characterized by instability and considerable variation in plant life. Some characteristic plants are present at the highest level of the beach. These include sea rocket (Cakile edentula), beach pea (Lathyrus maritimus var. glaber), seaside spurge (Euphorbia polygonifolia), Russian thistle (Salsola kali), bugseed (Corispermum hyssopifolium), winged pigwed (Cycloloma atriplicifolium) and silverweed (Potentilla anserina). None of these plants are found in abundance and, as Curtis (1959) has noted, their presence and densities vary from year to year.

When dry, the sand washed up on the beaches may be transported by wind. If the wind is on-shore and of a sufficient velocity, the sand is carried landward and may be deposited about an obstacle, such as driftwood or a growing plant. Often this deposited material is reworked by winds from different directions to form ridges and dunes (Fig. 1 (B)). Over time these landforms are colonized by plants which stabilize them and initiate vegetational development leading eventually to the establishment of a climax or terminal community. In this study, development through ridge and dune




Map 6. Locations of sandy beaches, ridges and dunes with characteristic plant species.

stabilization will be considered in greater detail than the later stages leading to terminal forest communities.

In the dunes and ridges along the eastern Wisconsin shoreline, the most important species is the dune reed (Calamovilfa longifolia var. magna), which comprises 25-50% of the cover. This grass is drought resistant, an adaptation necessary for such dry areas, and also has the ability to spread rapidly by rhizomes and to generate adventitious roots quickly when covered by wind-blown sand. Other characteristic grasses with similar abilities for survival, but occurring in lesser numbers, are beach grass (Ammophila breviligulata), wild rye grass (Elymus canadensis) and dune wheat grass (Agropyron dasystachyum var. psammophilum). In an earlier report Curtis (1959) indicated beach grass (Ammophila breviligulata) was the most common species. However, a study of the Point Beach dune area by Van Denack (1961) agrees with our findings that this species is not common and usually occurs on the more exposed dunes and ridges.

Forbs which assist in anchoring the sand include wormwood (Artemisia campestris), beach pea (Lathyrus maritimus), silverweed (Potentilla anserina), evening primrose (Oenothera biennis), old-field goldenrod (Solidago nemoralis) starry false Solomon's seal (Smilacina stellata) and the common milkweed (Asclepias syriaca). Shrubs present on the dunes and ridges are various willows (Salix lucida, S. interior, S. glaucophylloides, and S. cordata), wild rose (Rosa blanda), pin cherry (Prunus pensylvanica) and, not infrequently, poison ivy (Toxicodendron radicans var. rydbergii). A more detailed list is found in Appendix I and the rare or endangered species are listed in Appendix III.

The dune and ridge plant communities in Sheboygan, Manitowoc and Door Counties have the greatest numbers of these species. Transects were established in Terry Andrae State Park (Sites 24 and 25) in Sheboygan County, Point Beach State Forest (Site 26) in Manitowoc County, and Whitefish Bay (Site 28), North Bay (Site 29), Rowley Bay (Site 30), Moonlight Bay (Site 31) and Ridges Sanctuary at Baileys Harbor (Site 32) all in Door County. At these sites, except for the dunes at Terry Andrae State Park, the sands are stabilized to the extent that mat-forming shrubs and tree species have become established. These shrubs include the common juniper (Juniperus communis var. depressa), creeping juniper (Juniperus horizontalis) and occasionally bearberry (Arctostaphylos uva-ursi) and the American yew (Taxus canadensis). Tree species which have become established are white pine (Pinus strobus), paper birch (Betula papyrifera), red oak (Quercus borealis) and balsam poplar (Populus balsamifera).

The northern portion of Terry Andrae State Park (Site 25) and the adjoining J. M. Kohler State Park contain moving dunes as a result of disturbance caused by visitors traversing the area. Blowouts are present and most ridges are vegetated only with grasses and forbs characteristic of the early stabilization stages.

In the Door County sites, other northern tree species are present on the stable ridges, including yellow birch (Betula alleghaniensis), hemlock (Tsuga canadensis), spiked maple (Acer spicatum), and, in some few sites,

white spruce (Picea glauca) and balsam fir (Abies balsamea). These last two species occur mostly on the gentle sloping shorelines at North Bay (Site 29), Rowley Bay (Site 30) and at Toft Point on Moonlight Bay (Site 31). Some of the largest trees in Door County are found at Toft Point, an area that has been protected since the turn of the century. White pines (Pinus strobus) nearly three feet in diameter and white spruces (Picea glauca) up to 15 inches were recorded. Other sites have been logged over and only second growth stands of these species were tallied. The understory species at these sites are characteristic of the northern and boreal forests, including snowberry (Symphoricarpos alba), buffalo berry (Shepherdia canadensis) thimble berry (Rubus parviflorus), honeysuckle (Lonicera canadensis), yew (Taxus canadensis), partridge berry (Mitchella repens) and such herbs as bluebead lily (Clintonia borealis), dwarf dogwood (Cornus canadensis), star-flower (Trientalis borealis) and enchanter's nightshade (Circaea alpina).

The Ridges Sanctuary (Site 32) consists of a long series of parallel ridges above the beach zone, separated by swales or sloughs (pannes). This pattern produces a wide range of soil moisture and considerable accumulation of organic material in the swales resulting in greatly different habitats. In this intricate pattern, a great diversity of plant species is present throughout the growing season. Some of the many species include the orchids (Cypripedium spp., Pogonia ophioglossoides, Calopogon pulchellus, Spiranthes cernua and Habenaria spp.), fringed gentian (Gentianopsis procera), lake iris (Iris lacustris), Arctic primrose (Primula mistassinica), dune goldenrod (Solidago spathulata var. gillmani). All of these and others listed in Appendix III should be considered as endangered or threatened species.

Both Toft Point and The Ridges Sanctuary are preserved as scientific areas but the other Door County sites investigated are in private ownership. The privately owned areas serve aesthetic and recreational uses and are not yet threatened with large scale housing or commercial development. The desirability of preserving the Door County bays for wildlife habitat was noted earlier.

In Kenosha County, at site 23, the dune area is covered almost 50% by the dune reed (Calamovilfa longifolia var. magna). Other grasses, such as wild rye grass (Elymus canadensis) and June grass (Poa compressa) have a total cover of less than 25%. Other herbaceous plants present are horsemint (Monarda punctata), wormwood (Artemisia campestris), common milkweed (Asclepias syriaca), evening primrose (Oenothera biennis) and weeds such as dandelion (Taraxacum officinale), horseweed (Conyza canadensis) and white sweet clover (Melilotus alba). The presence of weeds is the result of disturbance by motorcyclists and pedestrians who have created large bare areas causing some blowouts to occur and creating openings in which these species became established. This dune area also contains a few shrubs, wild rose (Rosa blanda) wild grape (Vitis aestivalis) and poison ivy (Toxicodendron radicans var. rydbergii). No rare, endangered or threatened species were noted.

At the beach level, at the northeast edge of this area, logs and roots of a buried forest have been collected from a partially inundated clay bank. The US Forest Products Laboratory, Madison, Wisconsin has identified some of these remains as ash (Fraxinus sp.) and oak (Quercus sp.)(Sanders 1969).

Their age, determined by $C^{14}$ analysis, is 6,340 ± 300 years. Unfortunately, the land owner, the Wisconsin Electric Power Company, recently placed rip-rap along the entire shoreline and covered this scientific site.

At Site 22, three and one-half miles to the south, the beach and ridge plant communities show characteristics different from similar areas in Sheboygan, Manitowoc and Door Counties. The beach at Site 22 has been altered by deposits of litter and large concrete blocks, presumably placed to control the erosion of the first ridge or foredune upon which a service road had been built. Only a few typical beach plants are present, but many weeds have become established, including cocklebur (Xanthium stromarium), quack grass (Agropyron repens), cinquefoil (Potentilla recta), lesser ragweed (Ambrosia artemisiifolia), butter and eggs (Linaria vulgaris) and sow thistle (Sonchus asper).

For a distance of 30 meters from the beach the gently undulating ridges and swales have been disturbed by a housing development which, however, failed in the 1930s and most of the area has been revegetated by weedy and prairie species. Weeds present are common milkweed (Asclepias syriaca) fleabane (Erigeron strigosus), yarrow (Achillaea millifolium) and the late goldenrod (Solidago gigantea). Prairie species which have invaded the area include the gayfeather (Liatris pycnostachya), prairie phlox (Phlox glaberrima), puccoon (Lithospermum canescens), black-eyed susan (Rudbeckia hirta) and heath aster (Aster ericoides). Beyond this revegetated area, typical wet prairie species are more prominent. Species with high cover values (5-25%) in this tract are the coarsely serrate sunflower (Helianthus grosseserratus), grass-leaved goldenrod (Euthamia graminifolia), whorled loosestrife (Lysimachia quadrifolia), Joe-pye weed (Eupatorium maculatum), boneset (Eupatorium perfoliatum), New England aster (Aster novaeangliae), and Ohio goldenrod (Solidago ohioensis). Grasses were not well developed at the time of the survey, but the common species here are slough grass (Spartina pectinata) and the weedy reed canary grass (Phalaris arundinacea). Endangered and threatened species which have been observed or collected in this area include the Ohio goldenrod (Solidago ohioensis), fringed gentian (Gentianopsis procera), low nut grass (Scleria verticillata), calamint (Satureja glabella var. angustifolia) and the Great Lakes endemic, shrubby St. John's-wort (Hypericum kalmianum).

This shoreline area in Kenosha County is almost entirely privately owned, and undoubtedly will suffer from additional future residential development. Some of the homes already constructed are located on the foredune and, during the present high lake level, are being undermined by wave action. The owners have attempted to save their properties by dumping an assortment of material as rip-rap on the beach areas.

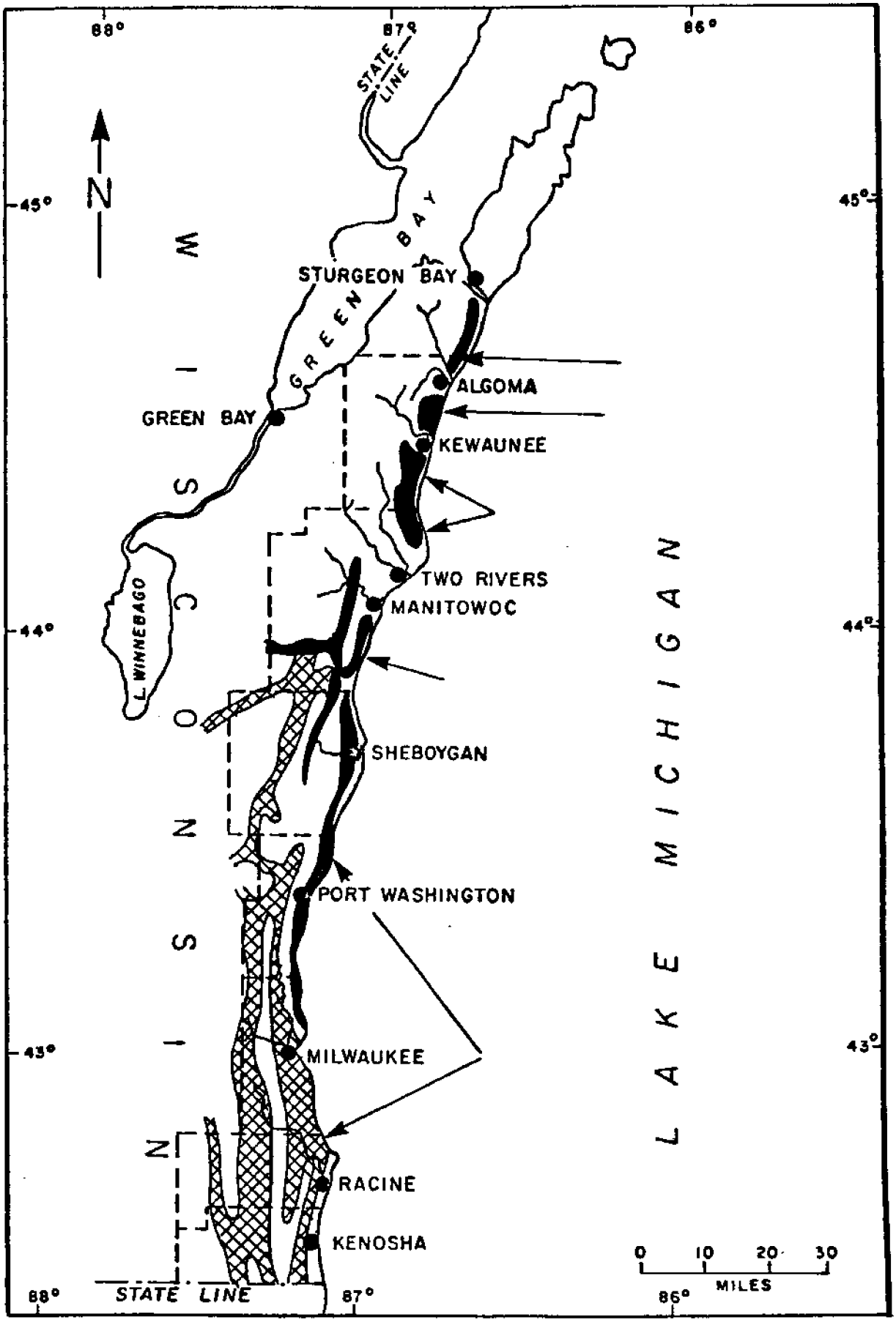
In general, the sandy beaches, ridges and dunes along the eastern Wisconsin shoreline are stable and able to withstand the wave action of even the most severe storms, especially where vegetation has been established. Ridges and dunes which have been subjected to residential development and extensive recreational use where the vegetative cover has been disturbed, have suffered from wind and water erosion. Restoration can be accomplished by periodic closing of the overused areas, together with some planting of native grasses (Gray 1976).

## Bluffs, Lake Terraces and Ravines

Clay bluffs of varying heights, slopes and stability extend from northeastern Racine County to northern Ozaukee County and some portions of southeastern and northeastern Manitowoc County, southeastern Kewaunee County, north of Algoma in Kewaunee County and in southeastern Door County (Map 7). These bluffs are composed of complex glacial deposits of the Wisconsin ice sheets. From southern Milwaukee County to northeastern Racine County, they are made up chiefly of gray-colored tills and lacustrine deposits of the Cary (Woodfordian) substage, while from the mouth of the Milwaukee River northward the reddish tills, outwash and lacustrine deposits of the Valders substage predominate. In post-glacial time the receding lake levels modified these deposits into bluffs with various slopes (Fig. 1 (C) & (E)). In some localities the lake recession was slower and terraces were formed. (Fig 1. (D)). Streams which discharge into the lake have developed steep-sided valleys or ravines. The lake terraces have gentle slopes and are relatively stable and not subject to much erosion. However, the bluffs and ravines, which are primarily silt and clay with some lenses and caps of sand and gravel, have been heavily eroded.

The pattern of bluff erosion, also applicable to ravine slopes, has been described on the basis of engineering principles (Edil and Vallejo 1976) which relate bluff recession rate to height and degree of slope, stress factors and lake level. Generally, bluff erosion results from degradation of the bluff face and the removal of material from the base or "toe" of the bluff. These processes are often initiated when the parent material has a high water content and is subjected to repeated wetting or drying or freezing and thawing. These actions reduce the binding of silt and clay particles with the result that slippage or slumping occurs. If there is no protective beach or other buffer area, the slumped material is removed by wave action at the toe or base of the bluff. Deep-rooted vegetation, especially trees, retard slumping by holding soil particles and reducing runoff from the bluff top to the slope face. Where sandy beaches, ridges, dunes or lake terraces are present, the force of wind-generated waves is absorbed and the slumped material may accumulate and over time decrease the slope angle and increase the stability of the bluff. Increased stability enables vegetation to become established and further reduce the erosion process.

The bluffs may be classified as either (1) stable bluffs or (2) eroding bluffs. Stable bluffs have slopes which are generally less than 35°, vegetated and have beaches or terraces at their bases. (Fig. 1, (C) & (D)). The vegetation of eight bluffs in northeastern Milwaukee County was examined (Sites 1, 2, 3, 5, 7, 8, 10, and 11). Four of these are County parks (Lake Park, Juneau Park, Big Bay Park and Doctors Park), one is an Audubon nature center and three are in private ownership. Plants found on these bluffs are characteristic of the Southern Mesic Forest (Curtis 1959). Some of the trees noted are red oak (Quercus borealis), basswood (Tilia americana), sugar maple (Acer saccharum), hop-hornbeam (Ostrya virginiana), and paper birch (Betula papyrifera). Native shrubs present are chokecherry (Prunus virginiana) red osier (Cornus stolonifera), round-leaved dogwood (Cornus rugosa), woodbine (Parthenocissus quinquefolia), wild grapes (Vitis spp.) and such introduced species as high-bush cranberry (Viburnum opulus) and Bell's honeysuckle




Map 7. Locations of clay bluffs, ravines and lake terraces associated with Cary (cross-hatches) and Valders (shaded) moraines.

(Lonicera X bella). The two latter species and the black locust (Robinia pseudo-acacia) have been widely planted in parks for ornamental purposes and for erosion control. They have been widely disseminated throughout the shoreline area by birds. Some native herbs persist, including the large flowering trillium (Trillium grandiflorum), blue and yellow violets (Viola spp.), blue cohosh (Caulophyllum thalictroides), early meadow rue (Thalictrum dioicum), geranium (Geranium maculatum) and other species listed in Appendix I. In the extreme northern part of Milwaukee County some species of boreal affinities are also present which include trees such as white pine (Pinus strobus), white cedar (Thuja occidentalis) and balsam poplar (Populus balamifera) and shrubs such as buffalo berry (Shepherdia canadensis), snowberry (Symphoricarpos albus) and the bush honeysuckle (Diervilla lonicera). Two threatened species have been collected here, but only at two of the sites. They are the yellow lady slipper orchid (Cypripedium calceolus) and pine drops (Pterospora andromeda), a seed plant parasitic on the roots of white pine.

In some parks the bluffs are criss-crossed with trails and show a decline in the diversity of understory species. In contrast, some of the bluffs in private ownership such as Cliff Terrace, in the Village of Shorewood (Site 2), the Schlitz Audubon Nature Center (Site 8) and the Fairy Chasm area (Sites 10 and 11) have remaining excellent assemblages of plants.

Bluffs of the second type, characterized by slopes varying from 45° to nearly 80° are eroding and unstable. Their slopes support limited vegetation and there is little or no beach or terrace at their bases. (Fig. 1 (E)). Four of the bluffs examined (Sites 4, 6, 9 and 10) are in county parks and the others (Sites 13, 14, 15, 16, 17 and 21) are privately owned. All of these bluffs are in Milwaukee and Ozaukee Counties. In pre-settlement times these bluffs varied in stability depending upon the degree of slope, fluctuations in lake levels and the extent of beach and the nature of vegetation on the face and bluff top. The construction of homes on the bluff tops as well as development of parkland and vistas resulted in increased runoff, less penetration of water into the soil and the initiation of gullying and slumping on the bluff faces. The slopes of the bluffs in Klode Park (Site 6), Virmond Park (Site 9), east of Cedarburg on County Highway C (Site 15), Notre Dame Convent property (Site 14) and east of Grafton on County Highway Q (Site 16) are irregular and less steep (nearly 35°) and support such trees as box elder (Acer negundo), willows (Salix spp.), ashes (Fraxinus spp.) and some black locust (Robinia pseudo-acacia). Shrubs which are present are essentially the same as those of the stable slopes, but the herbaceous flora has a high percentage of weedy species such as the goldenrods (Solidago altissima and S. juncea), bergamot (Monarda fistulosa), strawberry (Fragaria virginiana) and dandelion (Taraxacum officinale). Some of these slopes have approached stability but the removal of deep-rooted tree species from the bluff tops has resulted in slumping. The inundation of beaches by high water levels has also caused some undercutting at the base.

On slopes greater than 60°, especially where bluff tops have been denuded of trees, little or no vegetation was observed (Site 7, 19 and 21). Such slopes are readily observed north of Wind Point in Racine County, at Grant Park in South Milwaukee, Sheridan County Park in Cudahy, on private land

south of the power plant in St. Francis and on private land south of Port Washington in Ozaukee County. The slumped material often carries down some of the bluff top plants, including trees which have been undermined by the caving action of wave erosion. At the St. Francis power plant rip-rap has been placed on the beach and groins extended into the lake in an attempt to reduce wave damage to the shore area. This work has also caused increased erosion on the bluffs immediately south of the plant (Rosenbaum 1976).

These unstable bluffs have been subjected to greater erosion than any other shoreline features. The result has been considerable financial loss to owners of homes and commercial property on bluff ridges. Generally, vegetation has a minor role in controlling erosion on these steep bluffs unless the slopes can be graded to more gentle forms to enable plant establishment.

Lake terraces, formed during high lake levels of an earlier stage of Lake Michigan (Hough 1958) are found at the bases of some bluffs. Well-developed terraces were examined at Lake Park (Site 1), Cliff Terrace in Shorewood (Site 2), Juneau Park (Site 3) and at the Schlitz Audubon Nature Center (Site 8). These features also occur north of Port Washington in Ozaukee County, in Manitowoc County and south of Algoma in Kewaunee County (Fig. 1 (D)). These lake terraces range in width from 40 to 300 feet and vary in elevation from 3-6 feet above the lake at the present high water mark to 14-16 feet inland. Characteristic plant species are the same as those on the bluffs; however, most terraces have been extensively used for recreation in both private and in park lands and only scattered plants persist. On most terraces, ornamental trees and shrubs have been planted or the land has been cleared for picnic facilities, athletic fields and bicycle trails. Cliff Terrace in the Village of Shorewood (Site 2), has been used infrequently over the past 25-30 years and considerable revegetation was observed. Trees which have invaded this area are box elder (Acer negundo), several ashes (Fraxinus spp.), cottonwood (Populus deltoides), willows (Salix spp.) and smooth sumach (Rhus glabra) as well as such shrubs as tartarian honeysuckle (Lonicera tatarica), chokecherry (Prunus virginiana), highbush cranberry (Viburnum opulus) and two dogwoods (Cornus stolonifera; C. rugosa). Apparently, the native woody plants of nearby areas can quickly repopulate disturbed areas, but some introduced species are equally adaptable.

The erosion of these terraces is limited to the immediate beach line where some undercutting occurs during storms and during periods of high waves from strong on-shore winds. Generally, the terraces can withstand the force of the highest waves and, in this capacity, protect the bluffs.

Steep ravines, formed by streams cutting through the clay bluffs, are present in several localities along the shoreline. Well-developed ones were examined in detail at several sites in Milwaukee County. The ravines studied are in Lake Park (Site 1), Doctor's Park (Site 7), and in the Fairy Chasm area (Sites 12 and 13). Wherever the bluffs are stabilized by vegetation the ravines are also stable (e.g. Lake Park, Doctor's Park and Cliff Terrace). In the two sites in the Fairy Chasm area, construction of homes and clearing of bluff tops has resulted in considerable erosion of the slopes and many trees have been toppled, especially shallow-rooted species as white pine

(Pinus strobus), white cedar (Thuja occidentalis) and white birch (Betula papyrifera). Shrubs and herbs of the ravine slopes are the same species which occur on the bluff slopes but are more sparsely distributed. Some land owners have attempted to stabilize these ravines with plantings of black locust (Robinia pseudo-acacia), which has spread throughout the slopes, but more intensive management practices are necessary to reduce gullying if stability is to be achieved. Some retaining devices will be necessary to anchor the plantings until roots can become established to hold the substrate. Stems of cut brush, "wattles", imbedded in trenches which are perpendicular to the slopes have been used with considerable success on steep slopes in California (Gray 1976). Opportunities for the use of plants in combination with such mechanical devices as bulkheads, revetments and other supporting structures should be explored.

### Rocky Cliffs and Rock Outcroppings

The bedrock is exposed at several places in eastern Wisconsin (Map 1). Dolomitic shale (Devonian) appears in northeastern Milwaukee County and the eastern portions of Ozaukee and Sheboygan Counties but is inundated by the present high levels of Lake Michigan. Niagara dolomite (Silurian) outcrops in several localities in Door County. At Cave Point (Site 27), these outcrops extend 2-3 meters above the lake level forming low cliffs (Fig. 1(F)), that are subjected to considerable wave action but erode only gradually over very long periods of time. Other outcrops were observed at Toft Point (Site 31) along the southeastern shore of Moonlight Bay and along the causeway extending to Cana Island. These latter two outcrops are generally less than one meter above the present lake level (Fig. 1(G)) and are frequently inundated by high waves. The bare, exposed nature of these habitats makes them unsuitable for vascular plants, but they support several species of algae including Cladophora glomerata and Bangia atropurpurea (Blum, pers. comm.). The role of algae in these habitats has not been explored. Shoreward, beyond the extent of wave action, the vascular plant community consists chiefly of species of boreal or northern hardwood forests (Curtis 1959). These communities have been discussed in the section on Beaches, ridges and dunes.

## MAN-ALTERED FEATURES

Approximately 80-85% of the shoreline in eastern Wisconsin is in private ownership and the remainder is in state and county parks with a few scientific or educational preserves. In urban areas, the privately owned lands have been intensively developed for commercial and business use and most of the parkland has also been altered, to accommodate large numbers of people seeking recreation. Most of the remaining privately owned shoreline is now used for homesites or recreational cottages. These land uses have produced the following changes in the vegetation:

1. Aquatic and estuarine plants normally found at the mouths of streams discharging into Lake Michigan have been largely eliminated by the widening and deepening of these shoreline areas.

2. The native vegetation of many beaches, lake terraces and gentle bluffs has been eliminated or greatly modified through the development of bathing beaches, picnic areas, bicycle trails and athletic fields.

3. Native vegetation on slopes and bluff tops, especially forest has been removed or reduced for home construction, agricultural purposes or parkland development or merely to improve the view.

In addition to these changes a new shoreline type has been developed---the landfill. This feature has been created, chiefly in industrialized urban areas, to expand shoreline acreage for the construction of water and sewage facilities, marinas and shoreline roads and to control erosion. These fill areas (Fig.1(H)) are usually constructed by dumping large rocks, concrete slabs and excavation material into the shallow waters along the shoreline. When sufficient material has been accumulated, it is allowed to settle and then is graded. Construction work does not always begin immediately after the land fill but often the area remains vacant for several years. During this time weed species colonize the fallow land and some persist in disturbed or neglected areas after the land is developed. There they provide a seed source for other disturbed areas. Weeds are generally defined as those plants which grow spontaneously in habitats that have been greatly modified by human action, and are usually confined to such disturbed habitats. They are particularly well adapted to poor soils and have the ability to germinate from seed in a few weeks. Many weed species have seeds which can remain dormant in the soil for periods of 30-40 years, but germinate readily when the covering vegetation is removed.

Weed communities have received limited attention in respect to their development and relationship to native plants (Curtis 1959), but some general principles are reasonably well known. In newly created areas, annual weeds appear within a few weeks. Seeds of these plants are often carried in the fill material or may be transported to the site from nearby waste areas by wind or animals. If a fill area remains undeveloped for several years, the annual weed species are gradually replaced by perennial weeds and by introduced or native shrubs. Development beyond the shrub stage depends upon what other disturbances occur (e.g. grazing, off-road vehicles, burning, gardening, etc.). Theoretically, after several decades have passed, the original native vegetation can be expected to reclaim the land. However, a number of weedy herbs and shrubs appear to compete successfully with the native species and may become part of the re-established plant communities.

Only one landfill area (Site 20) was investigated in this work. This area, originally a lake terrace in Manitowoc County, was filled extensively more than 50 years ago. Filling was done to maintain a road between the cities of Manitowoc and Two Rivers. This fill extends nearly four miles and varies in width from 50-200 meters. A sandy-gravelly beach, approximately 10 meters in width separates the fill area from the water. Both the beach and the lakeward edge of the fill area are subjected to continuing disturbance from wind-driven waves. A two-mile section of the beach and adjacent fill were traversed and the various species of plants noted. Above the high water mark on the beach and on the adjoining fill, primarily herbaceous plants were tallied. They include high percentages of blue grass (Poa pratense),

quack grass (Agropyron repens), yarrow (Achillaea millifolium), knapweed (Centaurea maculosa), white sweet clover (Melilotus alba), ox-eyed daisy (Chrysanthemum leucanthemum), butter and eggs (Linaria vulgaris) and wormwood (Artemisia compestris). Shrubs noted in this zone include red osier dogwood (Cornus stolonifera), chokecherry (Prunus virginiana), rose (Rosa blanda), snowberry (Symphoricarpos albus) and the riverbank grape (Vitis riparia). Trees were present only on the stable fill bank and were chiefly ashes (Fraxinus spp.) but saplings were noted of quaking aspen (Populus tremuloides), cottonwood (Populus deltoides), box elder (Acer negundo), white birch (Betula papyrifera) and several willows (Salix spp.).

The same herbaceous weeds were found inland along the roadside and in open fields, indicating the probable seed source for the open habitats created along the beach and the eroding edge of the fill. This weedy plant assemblage appears to have persisted for a long time. Road maintenance, weed clearing and general upkeep of the various parks and view sites along this strip of land may be responsible for persistance of the weed population. However, it is apparent that both weedy and native plant species can persist on landfill areas.

## SUMMARY

Plant species which grow in the various shoreline habitats contribute significantly to the characteristics and stability of these landforms. In the protected bays and estuaries aquatic plants help maintain the high water quality which makes the areas suitable for wildlife and recreational use. Sandy beaches, ridges and dunes are generally stable because the sandy material dissipates the energy of waves and spray generated by storms and high winds. The plants adapted to the xerophytic conditions of these land forms also contribute significantly to stability by reducing wind erosion. Similarly, the gentle bluffs and lake terraces with well-developed vegetation on the slopes and bluff tops are less subject to erosion than the same types which have been denuded of vegetation. Steep clay bluffs are highly prone to erosion, particularly during high water, since wave action removes slumped material from the base of the bluffs and accelerates slope erosion. Erosion of these bluffs has been significantly increased wherever deep-rooted trees and shrubs have been removed from bluff tops. Replacement of erosion-controlling forest vegetation on these steep bluffs will often require expensive, special holding devices to enable plants to become established; therefore, bluffs which still retain a good forest cover should be protected and the tree cover included as an integral part of any development.

Vegetation for shoreline erosion control on the Great Lakes has not received sufficient attention but its value can no longer be overlooked. Long-range planning associated with the shoreline area, whether it involves residential development, commercial use, beach and bluff rebuilding, recreational development or the construction of landfill, should recognize the significance of vegetation for the stabilization of the several shoreline types, whether directly or in conjunction with mechanical and engineering devices.

## References


Alden, W.C. 1918. The Quaternary Geology of Southeastern Wisconsin. U.S. Geol. Surv. Prof. Paper 106. 356 pp.

Bauer, K.W. 1964. Regional Planning in Southeastern Wisconsin. Wis. Acad. Rev. 11 (344):2-6.

Black, R.F. 1970. Glacial Geology of Two Creeks Forest Bed, Valderian Type Locality and Northern Kettle Moraine State Forest. Wis. Geol. Nat. Hist. Surv. Info.Circ. No. 13, 40 pp.

_____ and M. Rubin. 1968. Radiocarbon Dates of Wisconsin. Trans.Wis. Acad. Sci. Arts and Lett. 56:99-116.

Blum, J. 1977. Personal communication.

Curtis, J.T. 1959. The Vegetation of Wisconsin: An Ordination of Plant Communities. Univ. of Wis. Press, Madison. 657 pp.

Durand, L. 1962. The Retreat of Agriculture in Milwaukee County. Trans Wis. Acad. Sci., Arts & Lett. 51:197-218.

Ekern, P.C. 1950. Raindrop Impact as the Force Initiating Soil Erosion. Ph.D. Thesis., Univ. of Wis. 81 pp.

Edil, T.B. and L.E. Vallejo. 1976. Shoreline Erosion and Landslides in the Great Lakes. Univ. of Wis. Sea Grant College Program, Advisory Report No. 15. 7 pp.

Environment Canada, 1976. The Vegetation Cover of the Great Lakes Canadian Shoreline: Its Role in Controlling Rates of Erosion. Areas Consulting Services Limited, Niagara Falls, Canada. 78 p. Appendix.

Flint, R.F. 1971. Glacial and Quaternary Geology. John Wiley & Sons Inc., New York. 892 pp.

Frye, J.C. & H.B. Willman and R.F. Black. 1965. Outline of Glacial Geology of Illinois and Wisconsin, pp. 43-61 in Wright, H.E. Jr. and D.G. Frye (eds). The Quaternary of the United States. Princeton Univ. Press, Princeton, N.J.

Fuller, A.M. 1932. Studies on the Flora of Wisconsin Part I. The Orchids (Orchidaceae) Bull. Publ. Mus. Milwaukee 14:1-284.

Gelinas, P.J. and R.M. Quigley. 1973. The Influence of Geology on Erosion Rates Along the North Shore of Lake Erie Proc. 16th Conf. Great Lakes Res., Internat. Assoc. Great Lakes Res., pp. 421-430.

Gleason, H.A. and A. Cronquist. 1963. Manual of Vascular Plants of Northeastern United States and Adjacent Canada. Van Nostrand Reinhold Co., New York. 810 pp.

Goder, H.A. 1957. Pre-settlement Vegetation of Racine County. Trans. Wis. Acad. Sci. Arts & Lett. 45:169-176.

Goldthwait, J.W. 1907. The Abandoned Shorelines of Eastern Wisconsin Wis. Geol. Nat. Hist. Surv. Bull. XVII. Scientific Series No. 5 134 pp.

Gray, D.H. 1974. Reinforcement and Stabilization of Soil by Vegetation. J. Geotsch. Eng. Dir. ASCE. Vol. 100, No. GT6, pp. 696-699.

_____. 1975. The Role and Use of Vegetation for the Protection of Backshore Slopes in the Coastal Zone. Manuscript, Univ. of Mich., Ann Arbor, Mich.

_____. 1976. The Influence of Vegetation on Slope Processes in the Great Lakes Region. Proceedings of the Workshop on the Role of Vegetation in Stabilization of the Great Lakes Shoreline. Gt. Lakes Basin. Comm:, Ann Arbor, Mich.

Guire, K.E. and E.S. Voss 1963. Distributions of Distinctive Shoreline Plants in the Great Lakes Region. Mich. Botanist 2:99-114.

Hadley, D.W. 1976. Shoreline Erosion in Southeastern Wisconsin. Univ. of Wis-Extension, Wis. Geol. Nat. Hist. Surv. Spl. Report No. 5.

Hall, V.L. and J.D. Ludwig. 1975. Evaluation of Potential Use of Vegetation for Erosion Abatement Along the Great Lakes Shoreline. U.S. Coastal Eng. Res. Ctr. Misc. Pap. (7) 1-35.

Harper, K.T. 1963. Structure and Dynamics of the Maple-Basswood Forest of Southern Wisconsin. Ph.D. Thesis, Univ. of Wis. Madison.

Hole, F.D. 1976. Soils of Wisconsin. Univ. of Wis. Press, Madison 223 pp.

Horn, M.E. 1954. A Pedological Study of Red Clay Soils and Their Parent Materials in Eastern Wisconsin. Ph.D. Thesis. Univ. of Wis.-Madison 238 pp.

Hough, J. 1958. Geology of the Great Lakes. Univ. of Ill. Press, Urbana. 313 pp.

Janke, W.E. 1962. Characteristics and Distribution of Soil Parent Materials in the Valderian Drift Region of Eastern Wisconsin. Ph.D. Thesis, Univ. of Wis. Madison. 152 pp.

Klahorst, H.A. Original Vegetation of Milwaukee County from Land Survey Records in Salamun P.J. 1957. Wisconsin's Trees and Plants 120 Years Ago. Historical Messenger. 3:6-10.

Lee, G.B. and M.E. Horn. 1972. Pedology of the Two Creek Section, Manitowoc County, Wisconsin. Trans. Wis. Acad. Sci. Arts & Lett. 60:183-199.

Link, E.G. and O.R. Demo. 1970. Soil Survey of Kenosha and Racine Counties, Wisconsin. U.S. Dept. of Agri., Soil Conserv. Serv. Washington, D.C. 113 pp.

Martin, L. 1932. The Physical Geography of Wisconsin. Wis. Geol. Nat. Hist. Surv. Bull. 36, Educ. Serv. No. 4. 608 pp.

Olson, G.W. and F.D. Hole. 1967. The Fragipan in Soils of Northeastern Wisconsin. Trans. Wis. Acad. Sci., Arts & Lett. 56: 174-184.

Omohundro, W. 1973. High Water and Shoreline Erosion on the Great Lakes. Shore and Beach 41 (1): 14-18.

Parker, D.E., D.C. Kurer and J.A. Steingraeber. 1970. Soil Survey of Ozaukee County, Wisconsin. U.S. Dept. of Agriculture, Soil Conservation Service, Washington, D.C. 94 pp ; 41 photo maps.

Petersen, G.W., G.B. Lee and G. Chesters, 1968. A Comparison of Red Clay Glacio-lacustrine Sediments in Northern and Eastern Wisconsin. Trans. Wis. Acad. Sci. Arts and Letters. 56:185-196.

Quigley, R.M. and Tutt. 1968. Stability, Lake Erie North Shore Bluffs. Proc. 11th Conf. Great Lakes Rec. pp. 230-238. Intl. Assoc. Great Lakes Res., Ann Arbor, Mich.

Read, R.H. 1976. Endangered and Threatened Vascular Plants in Wisconsin. Scientific Areas Preservation Council. Tech. Bull. No. 92. Wis. Dept. of Natural Resources, Madison.

Rosenbaum, J.G. 1976. Shoreline Structures as a Cause of Shoreline Erosion. A Review in Tank, R. (ed) Focus on Environmental Geology Oxford University Press, London.

Sanders, P. 1969. Kenosha Sand Dunes. Wis. Acad. Review 16(3):2-6.

Stearns, F.W. and N. Kobriger. 1975. Environmental Status of the Lake Michigan Region: Vol. 10 Vegetation of the Lake Michigan Drainage Basin. Argonne National Laboratory, Argonne, Ill.

Steingraeber, J.A. and C.A. Reynolds. 1971. Soil Survey of Milwaukee and Waukesha Counties, Wisconsin. U.S. Dept. of Agriculture, Soil Conservation Service. Washington, D.C. 177 pp., 138 photomaps.

Tans, W. 1976. Natural Area Inventory-Coastal Zone, Wisconsin. Scientific Areas Preservation Council. Wisconsin Dept. of Natural Resources, Madison.

Thwaites, F.T. 1943. Pleistocene of Part of Northeastern Wisconsin. Bull. Geol. Soc. Amer. 54:87-144.

_____ and K. Bertrand. 1957. Pleistocene Geology of the Door County Peninsula. Bull. Geol. Soc. Amer. 69:831-880.

US Army Corps of Engineers. 1971. Great Lakes Region Inventory Report National Shoreline Study - North Central Divsion. 221pp.

US Army Corps of Engineers. 1973. Great Lakes Shoreline Damage, Causes and Protective Measures. Gen. Inf. Pamphlet, North Central Division.

Van Denack, Sr. Julia Marie. 1961. An Ecological Analysis of the Sand Dune Complex in Point Beach State Forest, Two Rivers, Wisconsin. Bot. Gaz. 122(3):155-174.

Whitford, P. B. and P. J. Salamun. 1954. An Upland Forest Survey of the Milwaukee Area. Ecology 35(4):533-540.

Appendix I - Locations of the Sampling Sites and their Shoreline Features

| Site Number | Location & Ownership | Shoreline Habitat |
|---|---|---|
| 1 | Milwaukee County. Lake Park (Milwaukee County Park System) T7N, R22E, NW 1/4 Sec. 14. | Clay bluff with Lake terrace. |
| 2 | Milwaukee County. Village of Shorewood Cliff Terrace. Private Ownership. T7N, R22E, NE 1/4, Sec. 3. | Stable clay bluff with lake terrace. |
| 3 | Milwaukee County, Juneau Park (Milwaukee County Park System) T7N, R22E, NE 1/4 Sec. 28 | Stable wooded clay bluff & lake terrace. |
| 4 | Milwaukee County, Village of Whitefish Bay (Village Park) T8N, R22E, SW 1/4 Sec. 34 | Unstable clay bluff (wooded slope) |
| 5 | Milwaukee County, Big Bay Park in Whitefish Bay. (Milwaukee County Park System) T8N, R22E, SE 1/4 Sec. 33 | Stable, wooded clay bluff |
| 6 | Milwaukee County, Klode Park (Milwaukee County Park System) T8N, R22E, SW 1/4 Sec. 28 | Clay bluff with cleared, unstable top. |
| 7 | Milwaukee County, Doctor's Park (Milwaukee County Park System) T8N, R22E, SW 1/4, Sec. 10 | Stable, wooded clay bluff. |
| 8 | Milwaukee County, Schlitz Audubon Nature Center (Audubon Society) T8N, R22E, NW 1/4 Sec. 10 | Stable wooded, gentle bluff with lake terrace. |
| 9 | Ozaukee County, Virmond Park (Ozaukee County Park System) T9N, R22E, SW 1/4 Sec. 28 | Eroded clay bluff (much slumping) |
| 10 | Milwaukee-Ozaukee Counties. Privately owned land T9N, R22E, SW 1/4 Sec. 33 | Stable, wooded clay bluff. |
| 11 | North 1/8 mile from No. 10. | Stable, wooded clay bluff. |
| 12 | " " " " | Steep, eroding clay bluff. |
| 13 | " " " " | Eroding ravine slope |

| | | |
|---|---|---|
| 14 | Ozaukee County, Notre Dame of the Lake School (Private Property) T9N, R22E, SE 1/4 Sec. 8 | Eroding clay bluff with cleared top |
| 15 | Ozaukee County, East of Cedarburg on County Highway C. (Private) T10N, R22E, SW 1/4 Sec. 33 | Eroding clay bluff with farmland on top |
| 16 | Ozaukee County East of Grafton on County Highway Q. (Private) T10N, R22E, NE 1/4 Sec. 21 | Eroding clay bluff with farmland on top |
| 17 | Ozaukee County South of Port Washington (Private, Residential & Farm) T10N, R22E, NW 1/4 Sec. 10 | Eroding clay bluff |
| 18 | Ozaukee County, Harrington Beach (State Park) T12N R23C SW 1/4 Sec 18 | Sandy beach, sand ridges & swales. (site of former quarry operation--much fill.) |
| 19 | Milwaukee County, Grant Park (Milwaukee County Park System) T5N, R22E, NW 1/4 Sec. 1 | Eroding clay bluff (stabilized in some placed by wooded slopes.) |
| 20 | Manitowoc County. Lakeshore between Manitowoc and Two Rivers. T19N, R24E Secs. 10, 11, 16 | Lake terrace with fill material. |
| 21 | Racine County. Wind Point (Racine County Park System) T3N, R23E, SE 1/4, Sec. 27 | Eroding low clay bluff |
| 22 | Kenosha County. Chiwaukee Prairie (UW-Parkside) T1N, R23E, NE 1/4 Sec 32 | Sandy ridges & swales. |
| 23 | Kenosha County. Sand dunes area south of Kenosha (Wisconsin Electric Power Co.) T2N, R23E, NW 1/4 Sec. 8 | Sand dunes |
| 24 | Manitowoc County. Terry Andrae Park (State Park) T14N, R23E, NE 1/4, Sec. 27 | Sandy ridges and swales |
| 25 | Same except Dunes Area T14N, R23E, SE 1/4, Sec. 22 | Sand dunes |
| 26 | Manitowoc County. Point Beach State Forest (State Forest). T20N, R25E, NE 1/4, Sec. 16 | Sandy ridges and swales |

| | | |
|---|---|---|
| 27 | Door County. Cave Point (County Park) T28N, R27E, SE 1/4 Sec 2 | Limestone cliffs |
| 28 | Door County. Whitefish Bay (Town of Sevastopol) T28N, R27E, N1/2 Sec 10 | Sand dunes |
| 29 | Door County. North Bay (Private) T28N, R27E, SW Sec 22 | Wooded sandy beach, aquatic bay and estuary. |
| 30 | Door County. Rowley Bay (Private) T31N, R28E, E 1/2 Sec. 25 | Estuary, aquatic bay and wooded sandy beach |
| 31 | Door County. SE of Moonlight Bay Toft Point (UW-Green Bay) T30N, R28E SE 1/4 Sec 15 | Limestone outcrop, aquatic bay and wooded beach |
| 32 | Door County. Ridges Sanctuary. (Private Wildlife Preserve) T30N, R28E, SE 1/4 Sec. 17 | Sandy beach, wooded sandy ridges & swales. |

Appendix II. Annotated list of species found in plant communities of Lake Michigan shoreline habitats.

I. Bays and Estuaries

A. Estuarine Communities (Observations at the mouths of the Kewaunee and Ahnapee Rivers, Kewaunee County).

* 1. Bullrush - Scirpus sp. (probably S. validus)
* 2. Common Cattail - Typha latifolia L.

B. Aquatic Communities (including both shallow and deep water species in the sheltered bays in Door County). Sites 29, 30 and 31):

1. Water Plantain - Alisma plantago-aquatica L.
* 2. Sedges - Carex spp (difficult to distinguish without fruits)
* 3. Blue-joint- Calamagrostis canadensis (Mich.) Beauv.
4. Spike Rush - Eleocharis spp. (specimen not identifiable to species.
5. Manna Grass - Glyceria borealis (Nash) Batchelder.
6. Rushes - Juncus spp. (not identifiable to species because of the absence of flowers and fruits.
7. Duckweed - Lemna minor L.
8. Water milfoil - Myriophyllum sp. (not identifiable to species from the shore.)
9. Yellow Water Lily - Nuphar variegatum Engelm.
* 10. Reed Canary Grass - Phalaris arundinacea L.
11. Reed - Phragmites communis Trin.
12. Water Smartweed - Polygonum natans Eat.
13. Pondweed - Potamogeton sp. (not identifiable to species from the shore)
* 14. Arrowhead - Sagittaria latifolia Willd.
15. Willows - Salix spp. (not identifiable from the shore)
* 16. Bullrush - Scirpus validus Vahl.
17. Bur-reed - Sparganium eurycarpum Engelm.
* 18. Common Cattail - Typha latifolia L.
19. Eel Grass - Vallisneria americana Mich.
20. Wild Rice - Zizania aquatica L.

C. Shrub-Carr Communities (Sites 29 and 30):

Shrubs and Tree saplings:

1. Juneberry - Amelanchier sp. (No flowers or fruits for identification)
2. Speckled Alder - Alnus rugosa (Du Roi) Spreng.

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* Dominant or characteristic species.

C. Shrub-Carr Communities, continued.

* 3. Red-osier Dogwood - Cornus stolonifera (Michx.) Wang.
4. Tamarack - Larix laricina (Du Roi) K. Koch
5. Ninebark - Physocarpus opulifolius (L.) Maxim.
6. Quaking Aspen - Populus tremuloides Michx.
7. Meadow Sweet - Spiraea alba Du Roi
* 8. Willows - Salix spp. (not identifiable to species)
9. White Cedar - Thuja occidentalis L.

Herbaceous Plants:

* 1. Blue-joint - Calamagrostis canadensis (Michx.) Beauv.
2. Marsh Bellflower - Campanula aparinoides Pursh
* 3. Sedges - Carex spp. (not identifiable to species)
4. Turtlehead - Chelone glabra L.
5. Water Hemlock - Cicuta maculata L.
6. Willow-herb - Epilobium ciliatum Raf.
* 7. Marsh Horsetail - Equisetum palustris L.
* 8. Joe-Pye Weed - Eupatorium maculatum L.
9. Boneset - E. perfoliatum L.
10. White Snakeroot - E. rugosum Houtt.
11. Closed gentian - Gentiana andrewsii Griseb.
12. Jewel-weed - Impatiens biflora Walt.
13. Iris - Iris shrevei Small
14. Rush - Juncus sp. (not identifiable to species)
15. Water Parsnip - Sium suave Walt.
16. Reed - Phragmites communis Trin.
* 17. Late Goldenrod - Solidago gigantea Ait.

II. Beaches, Sandy Ridges and Dunes (Sites 18, 22, 23, 25, 26, 28 and 32)

A. Sandy Beaches (Strand Zone):

1. Quack Grass - Agropyron repens (L.) Beauv.
* 2. Sea Rocket - Cakile edentula (Bigel.) Hook. (includes var. edentula and var. lacustris Fern.)
* 3. Winged Pigweed - Cycloloma atriplicifolium (Spreng.) Coult.
4. Common Horsetail - Equisetum arvense L.
* 5. Seaside Spurge - Euphorbia polygonifolia L.
6. Beach Pea - Lathyrus maritimus (L.) Bigel. var. glaber (Ser.)Eames
7. Butter and Eggs - Linaria vulgaris Hill.
* 8. Silverweed - Potentilla anserina L.

B. Open Sandy Ridges and Dunes (Sites 22, 23, 25, 26, 28 and 32).

1. Yarrow - Achillaea millifolium L.
* 2. Dune Wheat Grass - Agropyron dasystachum (Hook.) Scribn. var. psammophilum (Gillett & Senn) E. Voss
* 3. Beach Grass - Ammophila breviligulata Fern.
4. Cress - Arabis lyrata L.; A. canadensis L.; A. laevigata (Muhl.) Poir.
* 5. Wormwood - Artemisia campestris L.
* 6. Common Milkweed - Asclepias syriaca L.
* 7. Dune Reed - Calamovilfa longifolia (Hook.) Scribn. var. magna Scribn. & Merrill
8. Horseweed - Conyza canadensis (L.) Cron.
9. Sand Coreopsis - Coreopsis lanceolata L.
10. Draba - Draba reptans (Lam.) Fern.
11. Wild Rye Grass - Elymus canadensis L.
12. Strand Wheat - E. mollis Trin. (E. arenarius L. var. villosus Mey.)
13. Fleabane - Erigeron strigosus Muhl.
14. Boneset - Eupatorium perfoliatum L.
15. Dwarf Lake Iris - Iris lacustris Nutt.
16. Sedges - Carex garberi Fern. (and other species)
17. Dune Thistle - Cirsium pitcheri (Torr.) T & G.
18. Rushes - Juncus balticus Willd.; J. greenei Oakes & Tucker.
* 19. Beach Pea - Lathyrus maritimus (L.) Bigel var. glaber (Ser.) Eames
20. Puccoon. Lithospermum caroliniense (Walt.) MacMill.
21. Horsemint - Monarda punctata L.
22. June grass - Poa compressa L.
* 23. Silverweed - Potentilla anserina L.
24. Beach Plum - Prunus pumila L.
25. Bird Cherry or Pin Cherry - Prunus pensylvanica L.f.
26. Meadow Rose - Rosa blanda Ait.
* 27. Willows - Salix lucida Muhl; S. interior Rowlee; S. glaucophylloides Fern.; S. cordata Michx.
* 28. Starry False Solomon's seal - Smilacina stellata (L.) Desf.
* 29. Old-field Goldenrod - Solidago nemoralis Ait.
30. Dune-Goldenrod - Solidago spathulata DC. var. gillmani (Gray) Cron.
31. Ohio Goldenrod - Solidago ohioensis Riddell.
* 32. Lake Tansey - Tanacetum huronense Nutt.
33. Poison Ivy - Toxicodendron radicans (L.) Ktze. var. rydbergii (Small) Erskine (Rhus toxicodendron L.)
34. Summer Grape - Vitis aestivalis Michx.

C. Stabilized Sandy Ridges and Dunes (Sites 22 and 23). Plants observed chiefly in Kenosha County.

1. Swamp Milkweed - Asclepias incarnata L.
2. Heath Aster - Aster ericoides L.

3. Smooth Aster - Aster laevis L.
4. Grass-leaved Goldenrod - Euthamia graminifolia (L.) Nutt. (Solidago graminifolia (L.) Salisb.)
5. Fringed Gentian - Gentianopis procera (Holm.) Ma. (Gentiana procera Holm.
6. Sunflower - Helianthus grosseserratus Martens
7. Kalm's St. John's wort - Hypericum kalmianum L.
8. Harsh Blazing Star - Liatris aspera Michx.
9. Blazing Star - Liatris pycnostachya Michx.
10. Puccoon - Lithospermum caroliniense (Walt.) MacMill.
11. American Bugleweed - Lycopus americanus Muhl.
12. Whorled Loosestrife - Lysimachia quadrifolia L.
13. Winged Loosestrife - Lythrum alatum Pursh
14. Horsemint - Monarda punctata L.
15. Switch-grass - Panicum virgatum L.
16. Smooth Phlox - Phlox glaberrima L. subsp. interior Wherry
17. Mountain Mint - Pycnanthemum virginianum (L.) Durand & Jackson
18. Calamint - Satureja glabella (Michx.) Briquet var. angustifolia (Torr.) Swenson
19. Low Nut-rush - Scleria verticillata Muhl.
20. Slough Grass - Spartina pectinata Link
21. Blue Vervain - Verbena hastata L.

D. Stabilized Sandy Ridge, Dunes and Shallow Interdunal Areas (Sites 18, 25, 26, 28 and 32). Plants observed chiefly north of the tension zone - Sheboygan County to Door County.

Herbaceous Species

1. Umbellate Aster - Aster umbellatus Mill.
2. Grass Pink - Calopogon pulchellus (Sw.) R. Br.
3. Alpine Enchanter's nightshade - Circaea alpina L.
4. Bluebead Lily - Clintonia borealis (Ait.) Ref.
5. Bunchberry - Cornus canadensis L.
6. Yellow Ladyslipper - Cypripedium calceolus L. var. pubescens (Willd.) Correll
7. Northern Commandra - Geocaulon lividum (Richards) Fern.
   Fringed Gentian - Gentianopsis procera (Holm.) Ma. (Gentiana procera Holm.)
8. Rein Orchid - Habenaria sp.
9. Dwarf Lake Iris - Iris lacustris Nutt.
10. Bird's eye Primrose - Primula mistassinica Michx.
11. Northern Spikemoss - Selaginella selaginoides (L.) Link.
12. Dune Goldenrod - Solidago spathulata DC. var. gillmani (Gray) Cron.
13. Lake Tansey - Tanacetum huronense Nutt.
14. False Asphodel - Tofieldia glutinosa (Michx.) Pers.
15. Slender Arrow-grass - Triglochin palustre L.

Trees and Shrubs

1. Balsam fir - Abies balsamea (L.) Mill (Door County)
2. Juneberry - Amelanchier spp.
3. Bearberry - Arctostaphylos uva-ursi (L.) Spreng.
4. Yellow Birch - Betula alleghaniensis Britt. (B. lutea Michx.)
5. Paper Birch - Betula papyrifera Marsh.
6. Bittersweet - Celastrus scandens L.
7. Red-osier Dogwood - Cornus stolonifera (Michx.) Wang.
* 8. Bush Honeysuckle - Diervilla lonicera Mill. (includes var. hypomalaca Fern., in Door County)
9. White Ash - Fraxinus americana L.
10. Green Ash - Fraxinus Pensylvanica Marsh. var. subintegerrima (Vahl) Fern.
* 11. Common Juniper - Juniperus communis L. var. depressa Pursh
* 12. Creeping Juniper - Juniperus horizontalis Moench
13. Fly Honeysuckle - Lonicera canadensis Bartr.
14. Twining Honeysuckle - Lonicera dioica L. (probably var. glaucescens (Rydb.) Butters).
15. Partridge-berry - Mitchella repens L.
* 16. White pine - Pinus strobus L.
17. Norway or Red Pine - Pinus resinosa Ait.
18. White Spruce - Picea glauca (Moench) Voss (Door County)
19. Balsam Poplar - Populus balsamifera L.
20. Quaking Aspen - Populus tremuloides Michx.
21. Red Oak - Quercus borealis Michx. f.
22. Thimbleberry - Rubus parviflorus Nutt. (Door County.)
23. Red Raspberry - Rubus strigosus Michx.
24. Buffalo-berry - Shepherdia canadensis (L.) Nutt.
25. Snowberry - Symphoricarpos albus (L.) Blake
26. Yew - Taxus canadensis Marsh.
* 27. White Cedar - Thuja occidentalis L.
28. Hemlock - Tsuga canadensis (L.) Carr (Door County)

III. Clay Bluffs, Ravines and Lake Terraces. (Sites 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 19 and 21.

A. Stable Clay Banks, Ravine Slopes and Lake Terraces (Sites 1, 2, 3, 5, 6, 7, 8, 10 and 11.

Trees

1. Box Elder - Acer negundo L.
* 2. Sugar Maple - Acer saccharum Marsh.
3. Juneberry - Amelanchier sp. (probably A. laevis Wieg.)
* 4. Paper Birch - Betula papyrifera Marsh.
5. Blue-beech - Carpinus caroliniana Walt.
6. Bitternut Hickory - Carya cordiformis (Wang.) K. Koch
7. Hawthorn - Crataegus sp. (not identifiable to species)
8. Beech - Fagus grandifolia Ehrh.
* 9. White Ash - Fraxinus americana L.
* 10. Green Ash - Fraxinus pensylvanica Marsh. var. subintegerrima (Vahl) Fern.

11. Red Mulberry - Morus rubra L.
* 12. Hop-hornbeam - Ostrya virginiana (Mill.) K. Koch
* 13. White Pine - Pinus strobus L.
* 14. Cottonwood - Populus deltoides Bartr.
15. Quaking Aspen - Populus tremuloides Michx.
16. Black Cherry - Prunus serotina Ehrh.
17. White Oak - Quercus alba L.
* 18. Red Oak - Quercus borealis Michx. f.
19. Black Locust - Robinia pseudo-acacia L. (I)
* 20. Smooth Sumach - Rhus glabra L. (especially on lake terraces)
21. Willows - Salix spp. (not identificable to species)
* 22. White Cedar - Thuja occidentalis L.
* 23. Basswood - Tilia americana L.
24. American Elm - Ulmus americana L.
25. Slippery Elm - Ulmus rubra Muhl.

Shrubs

1. Bittersweet - Celastrus scandens L.
* 2. Round-leaved Dogwood - Cornus rugosa Lam.
* 3. Red-osier Dogwood - Cornus stolonifera (Michx.) Wang.
4. Bush Honeysuckle - Diervilla lonicera Mill.
5. Witch Hazel - Hamamelis virginiana L.
* 6. Bell's Honeysuckle - Lonicera X bella Zabel (I)
* 7. Tartarian Honeysuckle - Lonicera tatarica L. (I)
* 8. Chokecherry - Prunus virginiana L.
* 9. Buckthorn - Rhamnus catharticus L. (I)
* 10. Currant - Ribes americanum Mill.
11. Wild Rose - Rosa blanda Ait.
12. Buffalo Berry - Shepherdia canadensis (L.) Nutt.
13. Purple Nightshade - Solanum dulcamara L.
14. Snowberry - Symphoricarpos albus (L.) Blake
15. Wayfaring Bush -Viburnum lantana L. (I)
* 16. High-bush Cranberry - Viburnum opulus L. (I)
17. Arrow-wood - Viburnum refinesquianum Schult.
* 18. Wild Grape - Vitis riparia Michx.

Herbs

1. Maiden-hair Fern - Adiantum pedatum L.
2. White Baneberry - Actaea pachypoda Ell.
3. Garlic Mustard - Alliaria officinalis Andrz. (I)
* 4. Wild Leek - Allium tricoccum Ait.
5. Hog Peanut - Amphicarpa bracteata (L.) Fern.
* 6. Wild sarsaparilla - Aralia nudicaulis L.
7. Burdock - Arctium minus (Hill) Bernh. (I)
8. Jack-in-the-pulpit - Arisaema triphyllum (L.) Schott.
* 9. Large-leaved Aster - Aster macrophyllus L.

(I) Introduced species.

* 10. Simple Aster - Aster simplex Willd.
* 11. Yellow Rocket - Barbarea vulgaris R. Br. (I)
* 12. Blue Cohash - Caulophyllum thalictroides (L.) Michx.
13. Ox-eyed Daisy - Chrysanthemum leucanthemum L. (I)
* 14. Enchanter's Nightshade - Circaea quadrisulcata (Maxim.) Franch. & Sav.
15. Lily-of-the-valley - Convallaria majalis L. (I)
* 16. Field Horsetail - Equisetum arvense L.
17. Fawn Lily - Erythronium sp. (No flowers for identification)
* 18. Wild Strawberry - Fragaria virginiana Duchesne
* 19. Wild Geranium - Geranium maculatum L.
20. Canadian Avens - Geum canadense Jacq.
21. Cow Parsnip - Heracleum lanatum Michx.
22. Dame's Rocket - Hesperis matronalis L. (I)
* 23. Waterleaf - Hydrophyllum virginianum L.
24. Jewel-weed - Impatiens biflora Walt.
25. Wild Pea - Lathyrus ochroleucus Hook.
26. Wild Lily-of-the-valley - Maianthemum canadense Desf.
27. Smooth Sweet Cicely - Osmorhiza longistylis (Torr.) DC.
28. Common Plantain - Plantago major L. (I)
29. Solomon's Seal - Polygonatum pubescens (Willd.) Pursh
30. White Lettuce - Prenanthus alba L.
* 31. Kidneyleaf Buttercup - Ranunculus abortivus L. (I)
32. Early Buttercup - Ranunculus septentrionalis Poir.
33. Sheep Sorrel - Rumex acetosella L. (I)
34. Black Snakeroot - Sanicula marilandica L.
* 35. False Spikenard - Smilacina racemosa (L.) Desf.
36. Starry False Solomon's Seal - Smilacina stellata (L.) Desf.
37. Tall Goldenrod - Solidago altissima L.
38. Flexuous-stemmed Goldenrod - Solidago flexicaulis L.
39. Dandelion - Taraxacum officinale Weber (I)
* 40. Early Meadow-rue - Thalictrum dioicum L.
41. Red Clover - Trifolium pratense L. (I)
42. Bent-stalk Trillium - Trillium gleasoni Fern. (T. flexipes Raf.)
43. Large-flowered Trillium - Trillium grandiflorum (Michx.) Salisb.
44. Bellwort - Uvularia grandiflora Sm.
* 45. Stemless Blue Violets - Viola cucullate Ait.; V. sororia Willd.
* 46. Smooth Yellow Violet - Viola pubescens Ait. var. eriocarpa (Schwein.) Russell

B. Eroding Bluff Slopes and Ravine Slopes (Sites 4, 9, 12, 13, 14, 15, 16, 17, 19 and 21)

Trees and Shrubs (trees mostly seedlings and saplings)

* 1. Box Elder - Acer negundo L.
* 2. Red-osier Dogwood - Cornus stolonifera (Michx.) Wang.
3. Hawthorn - Crataegus spp.

* 4. Green Ash - Fraxinus pensylvanica Marsh. var. subintegerrima (Vahl) Fern.
* 5. Bell's Honeysuckle - Lonicera X bella Zabel (I)
6. Virginia Creeper - Parthenocissus quinquefolia (L.) Planch.
* 7. Cottonwood - Populus deltoides Bartr.
* 8. Chokecherry - Prunus virginiana L.
* 9. Buckthorn - Rhamnus catharticus L. (I)
* 10. Staghorn Sumach - Rhus typhina L.
11. Wild Currant - Ribes sp.
12. Black Locust - Robinia pseudo-acacia L. (I)
13. Wild Rose - Rosa blanda Ait.
14. Red Raspberry - Rubus strigosus Michx.
* 15. Willows - Salix spp.
* 16. Purple Nightshade - Solanum dulcamara L.
17. Basswood - Tilia americana L.
* 18. Poison Ivy - Toxicodendron radicans (L.) Ktze. var. rydbergii (Small) Erskine (Rhus toxicodendron L.)
19. American Elm - Ulmus americana L.
20. High-bush Cranberry - Viburnum opulus L. (I)
21. Wild Grape - Vitis riparia Michx.

Herbs

* 1. Yarrow - Achillae millifolium L. (I)
2. Quack Grass - Agropyron repens (L.) Beauv. (I)
3. Burdock - Arctium minus (Hill. )Bernh. (I)
4. Smooth Aster - Aster laevis L.
5. Chicory - Cichorium intybus L. (I)
6. Canada Thistle - Cirsium arvense (L.) (I)
7. Bull Thistle - Cirsium vulgare (Savi) Tenore (I)
* 8. Wild Carrot - Daucus carota L. (I)
* 9. Field Horsetail - Equisetum arvense L.
* 10. Daisy Fleabane - Erigeron strigosus - Muhl.
11. Grass-leaved Goldenrod - Euthamia graminifolia (L.) Nutt. (Solidago graminifolia (L.) Salisb.)
* 12. Butter and Eggs - Linaria vulgaris Hill (I)
13. Yellow Sweet Clover - Melilotus officinalis (L.) Lam. (I)
14. Kidneyleaf Buttercup - Ranunculus abortivus L. (I)
15. Curley Dock - Rumex crispus L. (I)
16. Tall Goldenrod - Solidago altissima L.
17. Early Goldenrod - Solidago juncea Ait.
18. Dandelion - Taraxacum officinale Weber (I)
19. Alsike Clover - Trifolium hybridum L. (I)
20. Red Clover - Trifolium pratense L. (I)

IV. Dolomitic Cliffs and Outcroppings (Sites 27 and 31).

No vascular plants, but the following Algae noted by Dr. J.L. Blum:

1. Bangia atropurpurea (Roth) Agardh.
2. Cladophora glomerata (L.) Kutz.

V. Disturbed Areas - Weed Communities (Site 20)

* 1. Yarrow - Achillaea millifolium L. (I)
* 2. Quack Grass - Agropyron repens (L.) Beauv. (I)
3. Amaranth - Amaranthus sp. (probably A. retroflexus L.)
* 4. Lesser Ragweed - Ambrosia artemisiifolia L.
5. Wormwood - Artemisia campestris L.
6. Knapweed - Centaurea maculosa Lam. (I)
7. Lamb's Quarters - Chenopodium album L.
* 8. Ox-eyed Daisy - Chrysanthemum leucanthemum L. (I)
* 9. Canada Thistle - Cirsium arvense (L.) Scop. (I)
10. Bull Thistle - Cirsium vulgare (Savi) Tenore (I)
11. Field Bindweed - Convolvulus arvensis L. (I)
* 12. Horseweed - Conyza canadensis (L.) Cron. (I)
* 13. Daisy Fleabane - Erigeron strigosus Muhl.
14. _____ - Galinsoga parviflora Cav.; G. ciliata (Raf.) (I) Blake (I)
15. Pepper Grass - Lepidium densiflorum Schrader (I)
* 16. Butter and Eggs - Linaria vulgaris Hill (I)
* 17. White Sweet Clover - Melilotus alba Desr. (I)
18. Evening Primrose - Oenothera biennis L.
19. Common Plantain - Plantago major L. (I)
* 20. Kentucky Blue-grass - Poa pratensis L. (I)
21. Self-heal - Prunella vulgaris L. (I)
22. Curly Dock - Rumex crispus L. (I)
* 23. Dandelion - Taraxacum officinale Weber (I)
24. Alsike Clover - Trifolium hybridum L. (I)
25. Red Clover - Trifolium pratense L. (I)

Invading trees and shrubs:

1. Box Elder - Acer negundo L.
2. Red-osier Dogwood - Cornus stolonifera (Michx.) Wang.
3. Green Ash - Fraxinus pensylvanica Marsh. var. subintegerrima (Vahl) Fern.
4. Chokecherry - Prunus virginiana L.
5. Wild Rose - Rosa blanda Ait.
6. Willows - Salix spp.
7. Wild Grapes - Vitis spp.

Appendix III. Endangered (E) and threatened (T) plant species of critical shoreline habitats. (Classification follows Read, 1976).

| | Common Name | Scientific Name | Shoreline Habitats: Open sandy beaches, dunes & ridges | Interdunal swales and wet areas | Stabilized dunes and ridges | Stabilized clays, bluffs & ravines |
|---|---|---|---|---|---|---|
| 1. | Dune Wheat Grass | Agropyron dasystachum (Hook.) Scribn. var. psammophilum (Gillette & Senn) E. Voss | T | | | |
| 2. | Sea Rocket | Cakile edentula (Bigel) Hook. (incl. vars. edentula and lacustris Fern.) | T | | | |
| 3. | Sand Reed | Calamovilfa longifolia (Hook.) Scribn. (incl. var. magna Scribn. & Merrill) | T | | | |
| 4. | Grass Pink | Calapogon pulchellus (Sw.) R. Br. | | T | | |
| 5. | Dune Thistle | Cirsium pitcheri (Torr.) T. & G. | T | | | |
| 6. | Sand Coreopsis | Coreopsis lanceolata L. | T. | | | |
| 7. | Hairy Bush Honeysuckle | Diervilla lonicera Mill. var. hypomalaca Fern. | | | T | |
| 8. | Strand Wheat | Elymus mollis Trin. (E. arenarius L. var. villosus Mey.) | T | | | |
| 9. | Marsh Horsetail | Equisetum palustre L. | T. | | | |
| 10. | Variegated Horsetail | Equisetum variegatum Schleich. | | T | | |
| 11. | Northern Commandra | Geocaulon lividum (Richards) Fern. | | | E | |
| 12. | Fringed Gentian | Gentianopsis procera (Holm.) Ma. (Gentiana procera Holm.) | | T | | |
| 13. | Kalm's St. John's-wort | Hypericum kalmianum L. | | T | | |
| 14. | Dwarf Lake Iris | Iris lacustris Nutt. (I. cristata ssp. lacustris (Nutt.) Iltis | | E | E | |

Appendix III (continued)

| | Common Name | Scientific Name | Shoreline Habitats: Open sandy beaches, dunes & ridges | Interdunal swales and wet areas | Stabilized dunes and ridges | Stabilized clays, bluffs and ravines |
|---|---|---|---|---|---|---|
| 15. | Clustered Broomrape | Orobanche fasciculata Nutt. | E | | | |
| 16. | Smooth Phlox | Phlox glaberrima L. ssp. interior Wherry | | | E | |
| 17. | Bird's eye Primrose | Primula mistassinica Michx.. | | T | | |
| 18. | Pine Drops | Pterospora andromedea Nutt. | | | | E |
| 19. | Heart-leaved Willow | Salix cordata Michx. (incl. S. syrticola Fern.) | E | | | |
| 20. | Low Calamint | Satureja glabella (Michx.) Briquet var. angustifolia (Torr.) Svenson | | E | | |
| 21. | Low Nut-grass | Scleria verticillata Muhl. | | | T | |
| 22. | Northern Spikemoss | Selaginella selaginoides (L.) Link | | E | | |
| 23. | Ohio Goldenrod | Solidago ohioensis Riddell | | T | | |
| 24. | Dune Goldenrod | Solidago spathulata DC. var. gillmani (Gray) Cron. | E | | | |
| 25. | Lake Huron Tansy | Tanacetum huronense Nutt. | E | | | |
| 26. | False Asphodel | Tofieldia glutinosa (Michx.) Pers. | | E | | |

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